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DOCUMENT NO. D6-58402

TITLE: TEMPERATURE DISTRIBUTIONS ON GREAT CIRCLE AIR ROUTES

MODEL General

ISSUE NO. 12 TO: DDC (DATE)

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## I. ABSTRACT

An accurate method of calculating the statistical monthly and annual distribution of ambient temperatures on Great Circle routes and over geographical regions is presented. An easy to operate computer program gives data in convenient graphical and tabular form for airplane system trade studies and performance calculations. ( )

## II. SUMMARY

Accurate information concerning the statistical distribution of enroute ambient temperatures at airplane cruise altitudes is required for many trade studies and performance calculations, and is particularly important when system performance is highly temperature dependent as, for example, in airplane air-conditioning system studies. This document describes a method of calculating the statistical monthly (January, April, July and October) and annual temperature distribution on any Great Circle route for pressures of 300, 200, 150, 100 and 50 millibars, corresponding approximately to altitudes of 30,000 feet, 40,000 feet, 45,000 feet, 53,000 feet and 68,000 feet.

The route temperature distributions are generated by a computer program. Inputs to the program are the coordinates of the terminal points. Output is in several forms, namely:

1. The route temperature distribution, showing the probability of exceeding any temperature, given in graphical form with the option of tabular form as well.
2. The percentage of the total time that the temperature lies within discrete intervals of specified medium and width, given in graphical form with the option of tabular form as well.
3. The mean and standard deviation of the normal curve which best approximates the actual temperature distribution, and the error associated with the normal curve approximation.

The graphical output is illustrated in Figures 6 and 7 for the Johannesburg to London route at 30,000 feet.

Meteorological data based on records compiled over long periods for a selected global network of points furnish the basis for the program.

Sections of an existing program (Boeing Document D6-6833TN, Program No. TAP003) are employed, as a subroutine, for the determination of mean temperatures and standard deviations at equidistant points 100-200

nautical miles apart along a Great Circle route. The results were then used in the earlier program to generate the route mean temperature and the mean value of the enroute standard deviations for many routes, as described in documents D6-15650-2 and D6-15650-4. Presentation of results in this form has the disadvantage that the averaging process obscures the effect of temperature variations along a route. Furthermore, representation of the temperature distribution by a normal curve results in a loss in accuracy. For some cases, and particularly for short East-West routes and for all routes at 40,000 feet, enroute temperature variations are small and the route-mean results will closely approximate the results developed in this document. However in many cases enroute temperature variations are significant, and misleading information about temperature extremes will be obtained if the route-mean results are employed to describe the enroute temperature distribution.

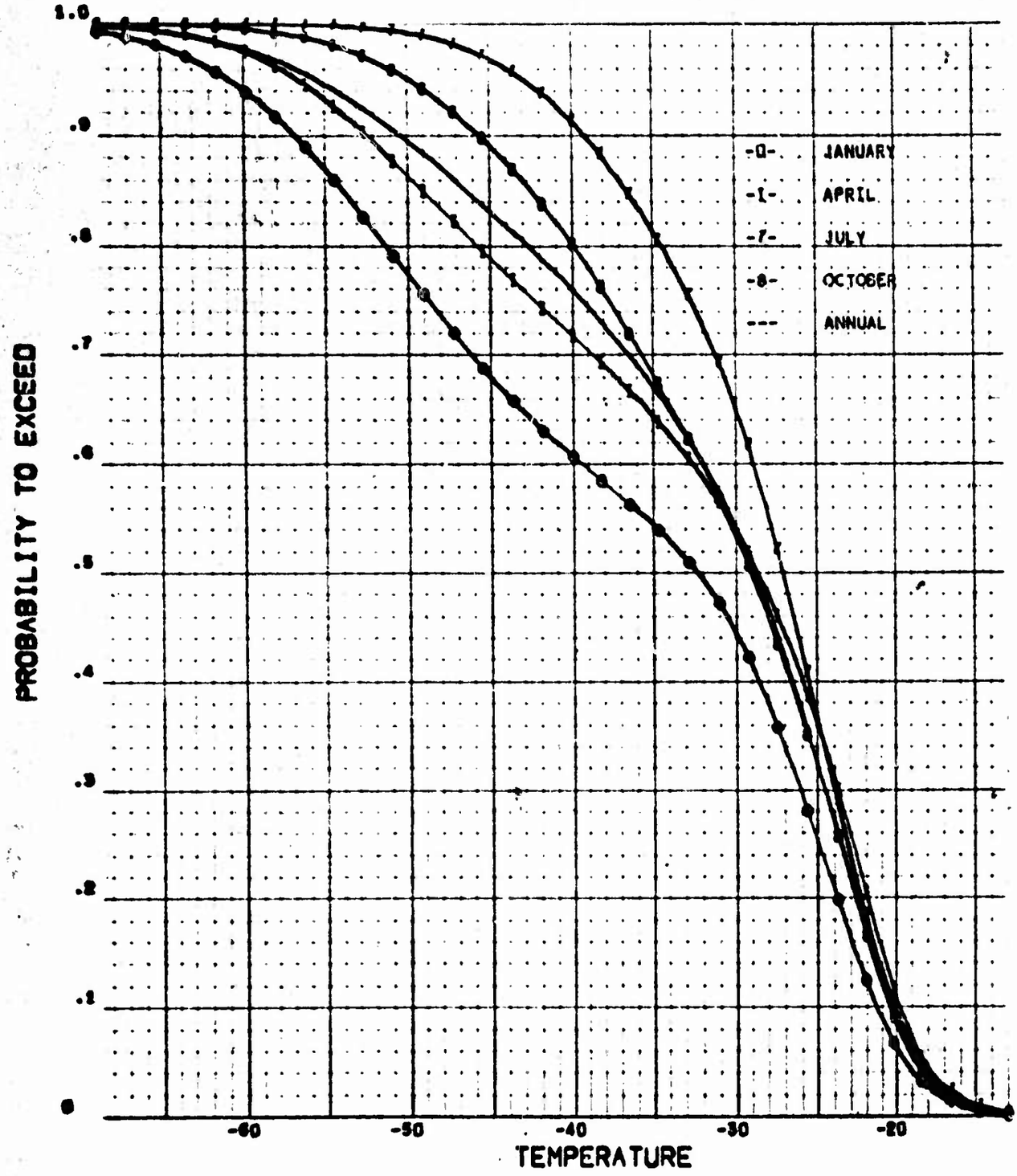
Temperature distributions for specific routes may prove unnecessary voluminous to a user who only requires information for a specific region of the earth. Therefore results are presented for four geographical regions of interest, namely:

1. The continental United States.
2. The continental United States combined with the North Atlantic and Central and Southern Europe.
3. The polar region of the Northern Hemisphere.
4. The equatorial region.

Temperature distributions for these regions are compared with the U. S. Standard Atmospheres, and it is shown that the Hot and Cold Atmospheres are encountered only over limited and often remotely located areas.

The advice and cooperation of Mr. Neal M. Barr (Atmospheric Engineering Group, Aerodynamic Staff) is acknowledged.

JOHANNESBURG TO LONDON
30,000 FT ALTITUDE




| | | | | | |
|---|---|---|---|---|---|
| CALC | | | REVISED | DATE | SEASONAL AND ANNUAL DISTR. FOR GIVEN ALT. AND ROUTE |
| CHECK | | | | | |
| APPR | | | | | |
| | | | | | BOEING |

FIG. 6

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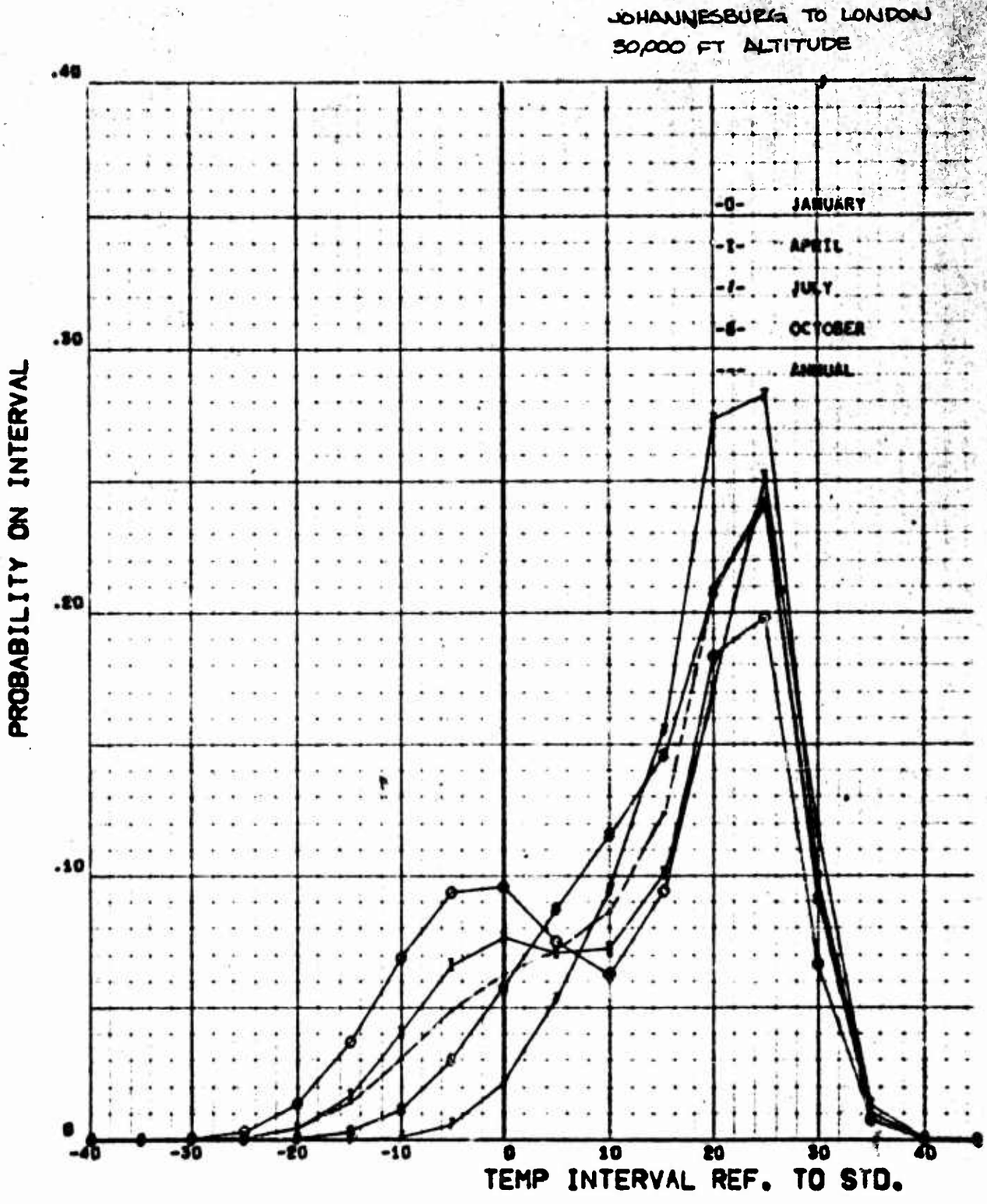


| | | | | | |
|---|---|---|---|---|---|
| CALC | | | REVISED | DATE | PROBABILITY ON INTERVALS OF SPECIFIED WIDTH |
| CHECK | | | | | |
| APPR | | | | | |
| APPR | | | | | |

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FIG. 7

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## III. INTRODUCTION

The ambient air temperature influences the performance of many airplane systems. Accurate information about this temperature is, therefore, of prime importance not only for trade studies but also for performance calculations.

Many different methods of estimating representative ambient temperature distributions have been used. One approach is to consider just the defined values of Standard, Hot and Cold Atmospheres, and to assume that these occur in fixed proportions (90 percent, 10 percent, 0 percent, for example). Such an approach is clearly very arbitrary and is unlikely to yield accurate results. Some of the shortcomings of this method are avoided by using the route-mean temperature data which have been compiled for many Great Circle routes (Reference 1). Route data in Reference 1 are given in the form of the route mean temperature, the mean value of the enroute standard deviations, and the temperatures that are not exceeded 50 percent, 75 percent and 85 percent of the time. The effect of inflight temperature variations is not reflected in these data and therefore information about temperature extremes calculated from the given mean temperature and standard deviation values, may be misleading.

The method of calculation described in this document avoids the approximations introduced in employing the route-mean data of Reference 1 to determine the enroute temperature distribution of a studied route, and the error involved in approximating the actual distribution by a normal curve. Both the developed method and the route-mean method use the same meteorological data. The deviation in the information about temperature extremes between the two methods is dependent on the magnitude of the enroute temperature variation, and this is in turn a complex function of the route, the altitude and the time of the year. In general, the difference increases with length of route, is greater for North-South than East-West routes, and is comparatively high at an altitude of 53,000 feet and low at 40,000 feet.

## IV. CALCULATION OF TEMPERATURE DISTRIBUTION ON A GREAT CIRCLE ROUTE

### A. METEOROLOGICAL DATA

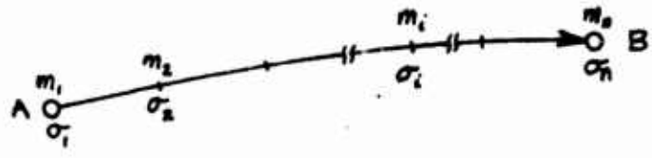
Meteorological data, based on records complied over long periods, have been obtained for a network of 1117 points covering the surface of the earth. The points are located at every latitude which is an exact multiple of five degrees. Within $60^{\circ}$ latitude of the equator, the points are located at every longitude which is an exact multiple of ten degrees; on those latitudes which are farther than $60^{\circ}$ from the equator the points are located at every longitude which is an exact multiple of twenty degrees. Each pole is represented by one point. The mean and standard deviation of a normal distribution fitted to the actual temperatures over a period of a month are recorded for each point. Data are available for January, April, July and October, these months being assumed to be representative of the seasons; and for pressures of 300, 200, 150, 100 and 50 millibar corresponding approximately to altitudes of 30,000 feet, 40,000 feet, 45,000 feet, 53,000 feet and 68,000 feet. Thus a total of 44,680 data values are available.

### B. GREAT CIRCLE ROUTE CALCULATION

If the geographical coordinates of the terminals of a route are specified, the Great Circle route may be determined by standard methods (Reference 2 for example). The coordinates of most major airports can be found in Reference 1.

### C. CALCULATION OF ROUTE TEMPERATURE DISTRIBUTION

If a route is divided into a number of equidistant points, the mean temperature ($m_i$), and standard deviation ($\sigma_i$) at each point (for a given month and altitude) may be obtained by interpolation from adjacent data points (Reference 2). Then if the temperature at any



point (i) is distributed normally, the probability that the temperature T at this point is less than or equal to any specified temperature $\vartheta$ is, by definition:

$$P(T \leq \vartheta) = F_N(\vartheta)_i = \frac{1}{\sqrt{2\pi}\sigma_i} \int_{-\infty}^{\vartheta} e^{-\left(\frac{T-m_i}{2\sigma_i}\right)^2} \, dT \qquad (1)$$

The probability that the temperature $\vartheta$ is exceeded is given by

$$P(T > \vartheta) = 1 - F_N(\vartheta)_i \qquad (2)$$

If the distance between points is chosen so that the temperature and standard deviation can be assumed constant during each flight increment, then the probability for the whole route of any specified temperature $\vartheta$ being exceeded is given by

$$P_R(T > \vartheta) = 1 - F_R(\vartheta) = \frac{\sum_{i=1}^{n} (1 - F_N(\vartheta)_i)}{n} \qquad (3)$$

An example of this method, using hand calculations to determine the cumulative probabilities, is shown in figures 1 and 2. In order to limit the number of calculations, the example uses larger temperature steps and fewer significant figures. The difference between the temperature distribution at selected points and the route temperature distribution is illustrated in figure 2.

The probability of the temperature falling within a specified interval is given by:

$$P(\vartheta < T \leq \vartheta + \Delta\vartheta) = F_R(\vartheta + \Delta\vartheta) - F_R(\vartheta) \qquad (4)$$

Assuming that the months of January, April, July and October are representative of the four seasons, the annual probabilities may be obtained. Thus:

$$P_{RA}(T > \vartheta) = 1 - F_{RA}(\vartheta) = \frac{\sum_{s=1}^{4} (1 - F_R(\vartheta))}{4} \qquad (5)$$

$$P_{RA}(\vartheta < T \leq \vartheta + \Delta\vartheta) = F_{RA}(\vartheta + \Delta\vartheta) - F_{RA}(\vartheta) \qquad (6)$$

D. FITTING OF A NORMAL CURVE

For most routes the temperature distribution closely approximates a normal curve. Since normal curves may be defined by specifying just the mean temperature and standard deviation, it is worthwhile determining the normal curve most closely approximating the actual distribution.

The mean temperature of the normal curve is calculated from the actual temperature which is exceeded 50% of the time and from temperatures having the defined probabilities of $\pm\, \sigma/2$ and $\pm\, \sigma$, thus averaging out discrepancies in any single value and giving:

$$m_F = \frac{1}{5} \left( \vartheta_{-\sigma} + \vartheta_{-\sigma/2} + \vartheta_{50} + \vartheta_{\sigma/2} + \vartheta_{\sigma} \right) \qquad (7)$$

The standard deviation is found by a similar method, averaging values at $\pm\, \sigma/2, \pm\, \sigma, \ldots\ldots, \pm\, 3\sigma$, and giving:

$$\sigma_F = \frac{1}{12} \left[ \sum_{2\gamma=-6}^{2\gamma=-1} \left( (\vartheta_\gamma - m_F)/\gamma \right) + \sum_{2\gamma=1}^{2\gamma=6} \left( (\vartheta_\gamma - m_F)/\gamma \right) \right] \qquad (8)$$

The mean and maximum deviations in $(1 - F_R(\vartheta))$ between the actual distribution and the fitted curve are calculated in order to indicate the accuracy of the curve-fitting.

E. CALCULATION OF A PROBABLE REGIONAL TEMPERATURE DISTRIBUTION

The available meteorological data can also be utilized to generate a probable temperature distribution that would apply to a geographical region of the earth rather than individual routes. The less voluminous results applicable to an airplane typically operating over the specified region are obtained at the expense of averaging

the temperature profiles over the region.

A method of calculation similar to Paragraph IV, C is used to generate the regional temperature distribution based on the meteorological data points located within the specified region. The spheroid shape of the earth is accounted for by giving area-balanced weights to individual points. Results are given in Appendix A.

## V. DESCRIPTION OF PROGRAM

A complete listing of the computer program for calculating enroute temperature distributions is given in Appendix B. It can be seen from the listing that the program is divided into a main program, five subroutines and a function subprogram. The main program handles input and output routines, and directs control to the subroutines and the function subprogram. The meteorological data is stored on a tape-unit (called TAPE8 for cross-reference) assigned to the author. The subprograms have the following functions:

1. Subroutine TEMP.

   Sections of an existing program (ref. 2) are used for generating mean temperatures and standard deviations at equidistant points 100-200 nautical miles apart along the specified route.

2. Subroutine DISTR.

   Determines the statistical temperature distribution for the whole route from the mean and standard deviation data for the individual points.

3. Subroutine FITNC.

   Determines the mean and standard deviation of the normal curve most closely approximating the calculated distribution curve.

4. Subroutine PINT.

   Determines the probability of the temperature being within intervals of given median and width. The system of median temperatures are centered around the Standard Atmosphere temperature.

5. Subroutine WBIN

   Prepared calculated data for input to the CDC-6600 system tape-writing subroutine WRTETP (ref. 4).

6. Function subprogram CNORML

   This subprogram calculates the cumulative probability for a normal distribution, given the mean and standard deviation and the region for which the probability is required (ref. document PS-497, Program Library Department).

Input for the program is described in Appendix C, and sample data for the route Johannesburg to London are included for illustration. It should be noted that exactly antipodal points must not be specified as terminals of a route since such points do not give a uniquely defined Great Circle route. Furthermore, meteorological data are not available on the 50 millibar (68,000' altitude) level south of latitude 55 S. A diagnostic is printed if the Great Circle route enters this region.

In order to reduce core storage requirements the DIMENSION statements have been written so that not more than two altitudes can be handled in any one run, and routes are restricted to a maximum length of 11,000 nautical miles.

Output data are in the form of graphs and tables and are self-explanatory. The plots are not labeled by route, but may be identified by the fact that they are generated in the same order that the routes are inputed. Tabular and graphical output corresponding to the input of Appendix C are shown in figures 5 through 7.

Appendix D shows a complete deck assembly and lists the required control cards. The Fortran nomenclature is shown in Appendix E. The core storage requirement is $110000_8$ and the central processor time is approximately equal to

$$CPT = 21.5 + 3.8 \times NALT \times NROUTE \text{ seconds}$$

## VI. EXAMPLE

### A. ROUTE TEMPERATURE DISTRIBUTION

Use of the program may be illustrated by considering a specific route, and Johannesburg to London at 30,000' has been selected. As this is a long route (4896 N.M.) and in a South-North direction, considerable enroute temperature variations can be expected. This is confirmed by reference to figure 3, which shows isotherms at 30,000' in January. Figure 4 shows that the standard deviations varies noticeably too.

The mean temperature and standard deviation for 26 equispaced points along the route are shown in figure 5, which also shows temperatures having a 50, 75 and 85% probability of not being exceeded. These values could also be obtained from the graphical plot of figure 6, and can be compared with values obtained using the route-mean method of reference 1. For the month of January, the comparison shows:

| Probability of Not Exceeding | Enroute Temperature Method | Route-Mean Method |
|---|---|---|
| 50% | -32.3F | -38 C ≃ -36F |
| 75% | -24.9F | -37 C ≃ -35F |
| 85% | -22.6F | -36 C ≃ -33F |

Figure 5 shows the mean and standard deviation of the normal distribution curve most closely resembling the actual temperature distribution, and also the error associated with the normal curve approximation. It can be seen that in this case, the normal curve is not a particularly good approximation. A comparison for the month of January with the values listed in reference 1 gives:

| | Enroute Temperature Method | Route-Mean Method |
|---|---|---|
| Mean Temperature | -36.1F | -38C ≃ -36F |
| Standard Deviation | -13.4F | 2C ≃ 4F |

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It can be seen that the route-mean method gives misleading information about the extremes of temperature that will be encountered on this route and this method, originally not intended to describe the enroute temperature distribution but frequently used in this capacity, should not be used where considerable enroute temperature variations can be expected.

It is interesting to apply the different methods of determining route temperatures to the calculation of the operating penalty of a system. Consider, as an example, the ram drag of the model 747 air conditioning system at .85 MN cruise. The ram drag is plotted in Figure 8 as a function of ambient temperature, with temperature histograms based on the statistical and route-mean methods superposed. The average route ram drag may be compared, giving:

| Method | | Average Drag lb/Airplane |
|---|---|---|
| Enroute temperature | | 799 |
| Route-Mean | | 396 |
| Standard Day | 90% | 415 |
| Hot Day | 10% | |

It can be seen that in this case the route-mean and Standard/Hot day methods seriously underestimate the average drag, and hence the average airplane penalty.

B. REGIONAL TEMPERATURE DISTRIBUTION

Appendix A introduces the use of the available meteorological data to generate a probable temperature distribution applicable to a specified region of the earth, thereby eliminating the high degree of idealization inherent to the use of standardized atmospheres. To illustrate the use of the generated data, an example involving the identical airplane-system as in the previous example will be presented. Two of the selected geographical regions in Appendix A (Continental United States and Equatorial region) at the 30,000 foot altitude will be studied.

From the annual temperature distribution curves for the two regions at the given altitude (Figures 14 and 17) one can easily obtain the

probabilities on 5 degrees Fahrenheit intervals for calculation of the average ram drag, as was done for an individual route in the previous section. Figure 10 gives the probability histograms for the two regions superposed on the ram drag curve. Comparison of the average ram drag gives:

| | Average drag lb/airplane |
|---|---|
| Standard Day 90% / Hot Day 10% | 415 |
| Probable temp. distribution over the Continental United States | 447 |
| Probable temp. distribution over the Equatorial region | 1260 |

It is seen that for the given example, the adopted combinations of the standardized atmospheres yields an acceptable value of the average drag if applied over the Continental United States. If another airplane system, having a different temperature dependence, was being studied, this might not have been the case. Taken over the equatorial region it is found that 90% Standard Day, 10% Hot Day seriously under-estimates the average drag, in spite of the fact that Hot Day (Hot Day = Std. Day + 40F at 30,000 ft.) is found to be exceeded $< 1\%$ of the year when focusing the entire equatorial region of the earth. Likewise it can be seen that temperatures as low as Standard Day are extremely unlikely to be encountered over this area, making an assumption of 90% of the time at Standard Day unrealistic. Finally if the interest is founded on localized areas where the concept of Hot Day applies (areas recording temperatures exceeding Hot Day 10% of the time), one will find that such as area at 30,000 feet exists over South East Asia. Calculations of the average drag based on the probable temperature distribution over this area will result in a value exceeding the one obtained for the Equatorial region, showing that if 10% Hot Day is a realistic figure, one can not designate Standard Day condition to the remaining portion of the time.

## VII. CONCLUSIONS AND RECOMMENDATIONS

The method for determining enroute temperatures developed in this document generates results which are limited in accuracy only by the accuracy of the meteorological data on which they are based. The computer program is simple to use and presents results in convenient tabular and graphical forms. Therefore, it is recommended that the statistical method should always be used for generating enroute temperature distributions. For some routes, and particularly for short East-West routes, the route-mean method (Reference 1) gives acceptable approximations of the enroute temperature distribution.

Use of the regional temperature data to designate a probable temperature distribution eliminates the high degree of idealization inherent to the use of standardized atmospheres, thereby greatly improving the accuracy and reliability of employed data. It is recommended that the regional temperature data be used instead of standardized atmospheres in determining typical operating temperatures for airplanes and airplane systems.

## VIII. FIGURES

## PROBABILITY TO EXCEED

JOHANNESBURG TO LONDON 4896 N.M.
30,000 FT ALTITUDE, JANUARY

| FLIGHT POINT | MEAN/STD | -62 | -58 | -54 | -50 | -46 | -42 | -38 | -34 | -30 | -26 | -22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | TEMPERATURE (CELCIUS) | | | | | | | | | | |
| 1 | 50/4 | 100 | 97.9 | 84.1 | 50.0 | 15.9 | 2.1 | | | | | |
| 2 | 50/4 | ↓ | 97.9 | 84.1 | 50.0 | 15.9 | 2.1 | | | | | |
| 3 | 49/4 | | 98.8 | 89.7 | 60.0 | 22.5 | 5.8 | .3 | | | | |
| 4 | 48/4 | | 99.4 | 93.5 | 69.5 | 30.5 | 6.5 | .6 | | | | |
| 5 | 47/3 | | 100 | 99.2 | 84.1 | 36.4 | 4.5 | .1 | | | | |
| 6 | 47/3 | | ↓ | 99.2 | 84.1 | 36.4 | 4.5 | .1 | | | | |
| 7 | 46/3 | | | 99.7 | 91.1 | 50.0 | 8.7 | .3 | | | | |
| 8 | 45/3 | | | 99.9 | 95.2 | 62.8 | 15.9 | .9 | | | | |
| 9 | 44/3 | | | 100 | 99.9 | 84.1 | 15.9 | .1 | | | | |
| 10 | 42/2 | | | ↓ | 100 | 97.7 | 50.0 | 2.2 | | | | |
| 11 | 40/2 | | | | ↓ | 99.9 | 84.1 | 15.9 | .1 | | | |
| 12 | 38/2 | | | | | 100 | 97.7 | 50.0 | 2.2 | | | |
| 13 | 36/2 | | | | | ↓ | 99.9 | 84.1 | 15.9 | .1 | | |
| 14 | 35/2 | | | | | | 100 | 95.2 | 30.2 | .6 | | |
| 15 | 34/2 | | | | | | ↓ | 97.6 | 50.0 | 2.2 | | |
| 16 | 33/2 | | | | | | | 99.3 | 69.8 | 6.5 | | |
| 17 | 32/2 | | | | | | | 99.9 | 84.1 | 15.9 | .1 | |
| 18 | 32/2 | | | | | | | 99.9 | 84.1 | 15.9 | .1 | |
| 19 | 31/2 | | | | | | | 100 | 93.2 | 30.2 | .6 | |
| 20 | 31/2 | | | | | | | ↓ | 93.2 | 30.2 | .6 | |
| 21 | 30/2 | | | | | | | | 97.6 | 50.0 | 2.2 | |
| 22 | 30/2 | | | | | | | | 97.6 | 50.0 | 2.2 | |
| 23 | 30/2 | | | | | | | | 97.6 | 50.0 | 2.2 | |
| 24 | 30/2 | | | | | | | | 97.6 | 50.0 | 2.2 | |
| 25 | 31/3 | | | | | | | 99.0 | 84.1 | 37.1 | 4.9 | |
| 26 | 33/3 | | | | | | 99.9 | 95.1 | 62.9 | 15.9 | 1.0 | |
| $\sum_{i=1}^{26} \frac{(1-F_{W(x)i})}{26}$ | | 100 | 99.8 | 98.1 | 91.7 | 76.9 | 65.2 | 56.3 | 40.8 | 13.6 | .6 | 0 |

HAND CALCULATION OF ROUTE TEMPERATURE DISTRIBUTION

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FIG. 1

CALC | CHECK | APPD | APPD | DATE | REVISED | DATE

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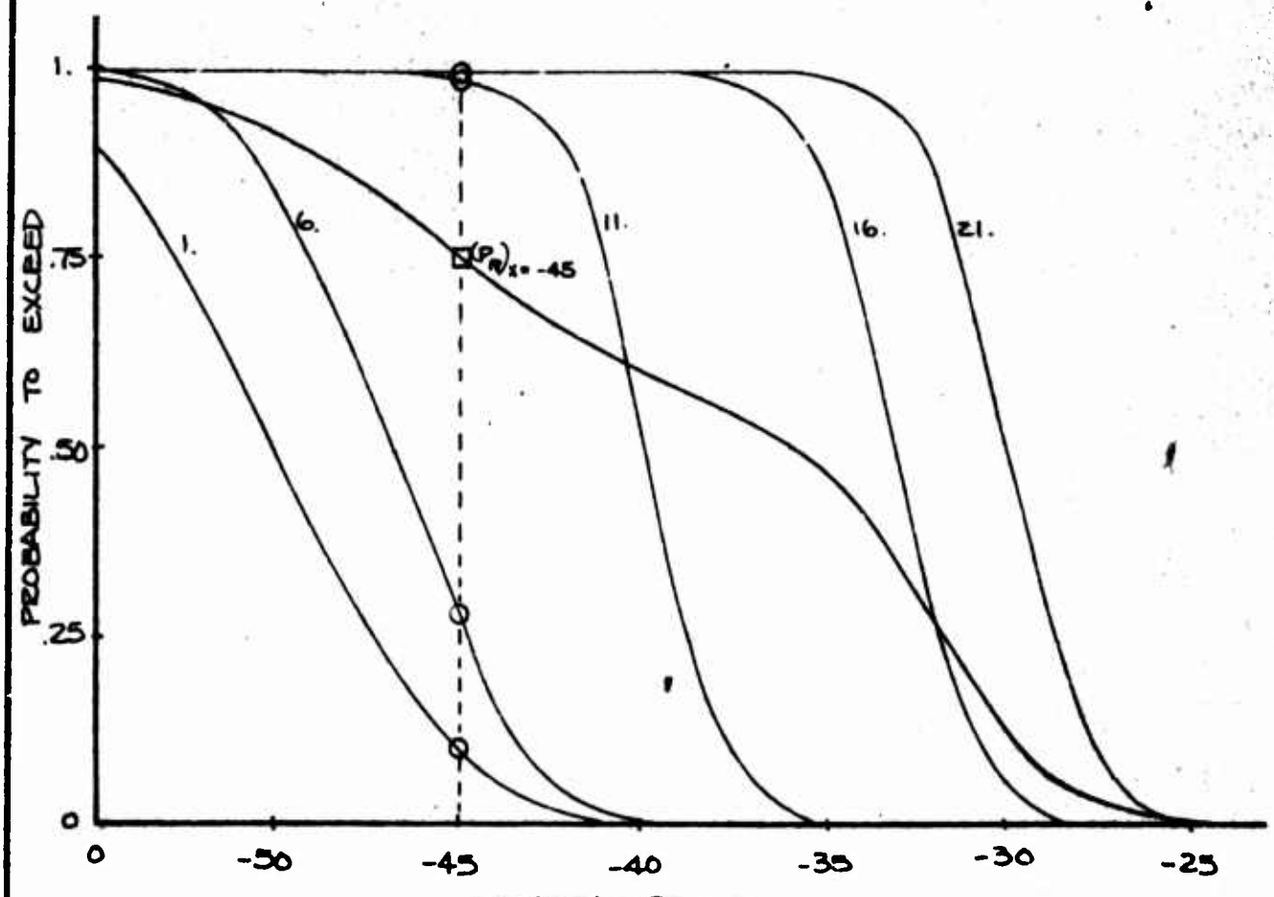
JOHANNESBURG TO LONDON
30,000 FT, JANUARY
CONT.

THE NORMAL DISTRIBUTION CURVE FOR A NUMBER OF SELECTED POINTS IS SHOWN BELOW. THE CURVE (NON-NORMAL) BASED ON THE CALCULATED DATA IN FIGURE GIVES THE DISTRIBUTION FOR THE ENTIRE ROUTE.




EXAMPLE: $(P_R)_{x=-45} = \frac{\sum_{1}^{26} (P_i)_{x=-45}}{26} = 75.4\%$

| | | | | | | |
|---|---|---|---|---|---|---|
| CALC | | | REVISED | DATE | HAND CALCULATED ROUTE TEMPERATURE DISTRIBUTION CURVES | FIG. 2 |
| CHECK | | | | | | |
| APPD | | | | | | D6-58402 |
| APPD | | | | | | |
| DR | | | | | THE BOEING COMPANY RENTON, WASHINGTON | PAGE 21 |

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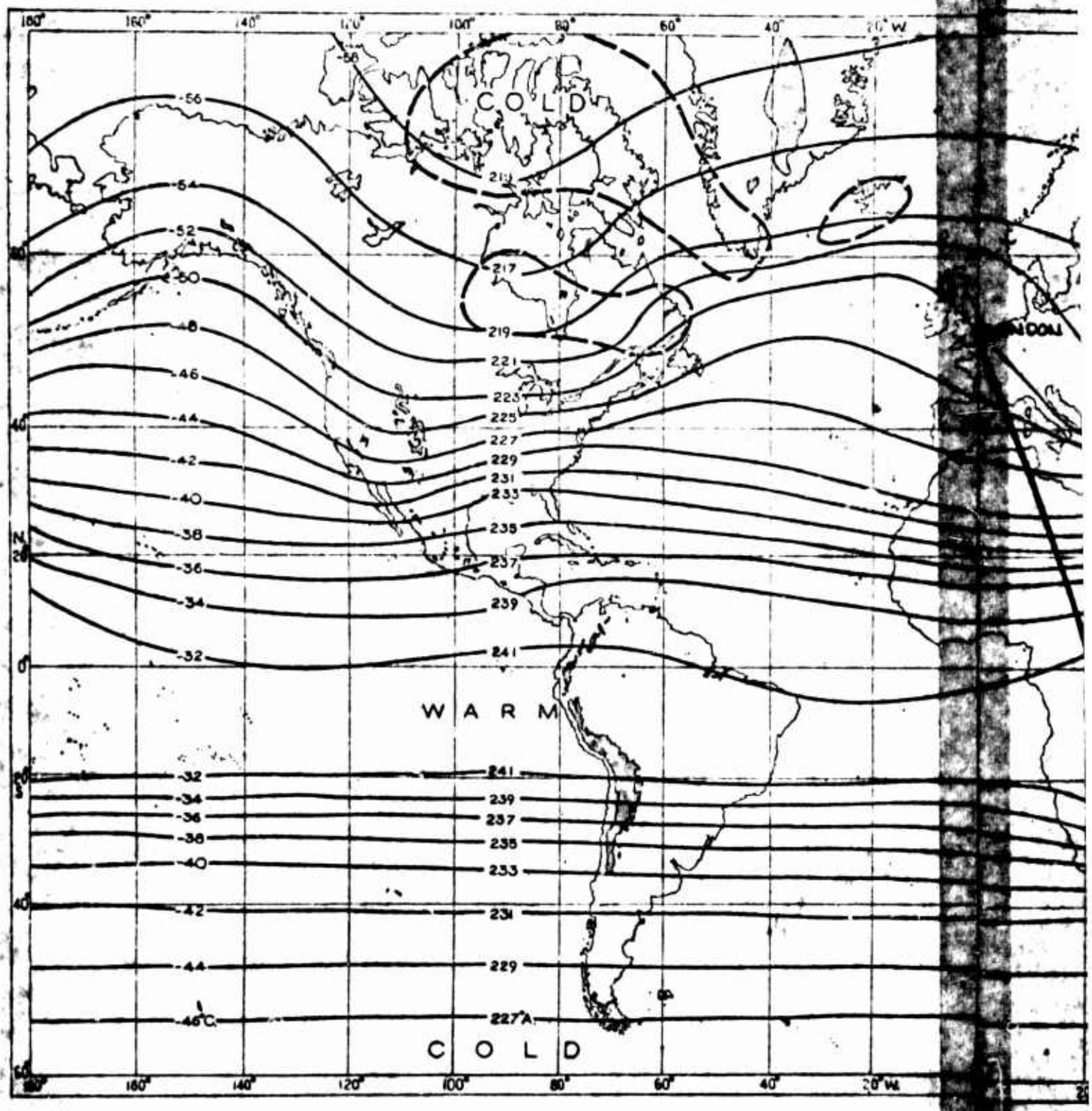


AVERAGE TEMPERATURE AT 300 MB. IN JANUARY
UPPER AIR TEMPERATURE OVER THE WORLD
N. GOLDIE, J.G. MOORE AND E.E. AUSTIN

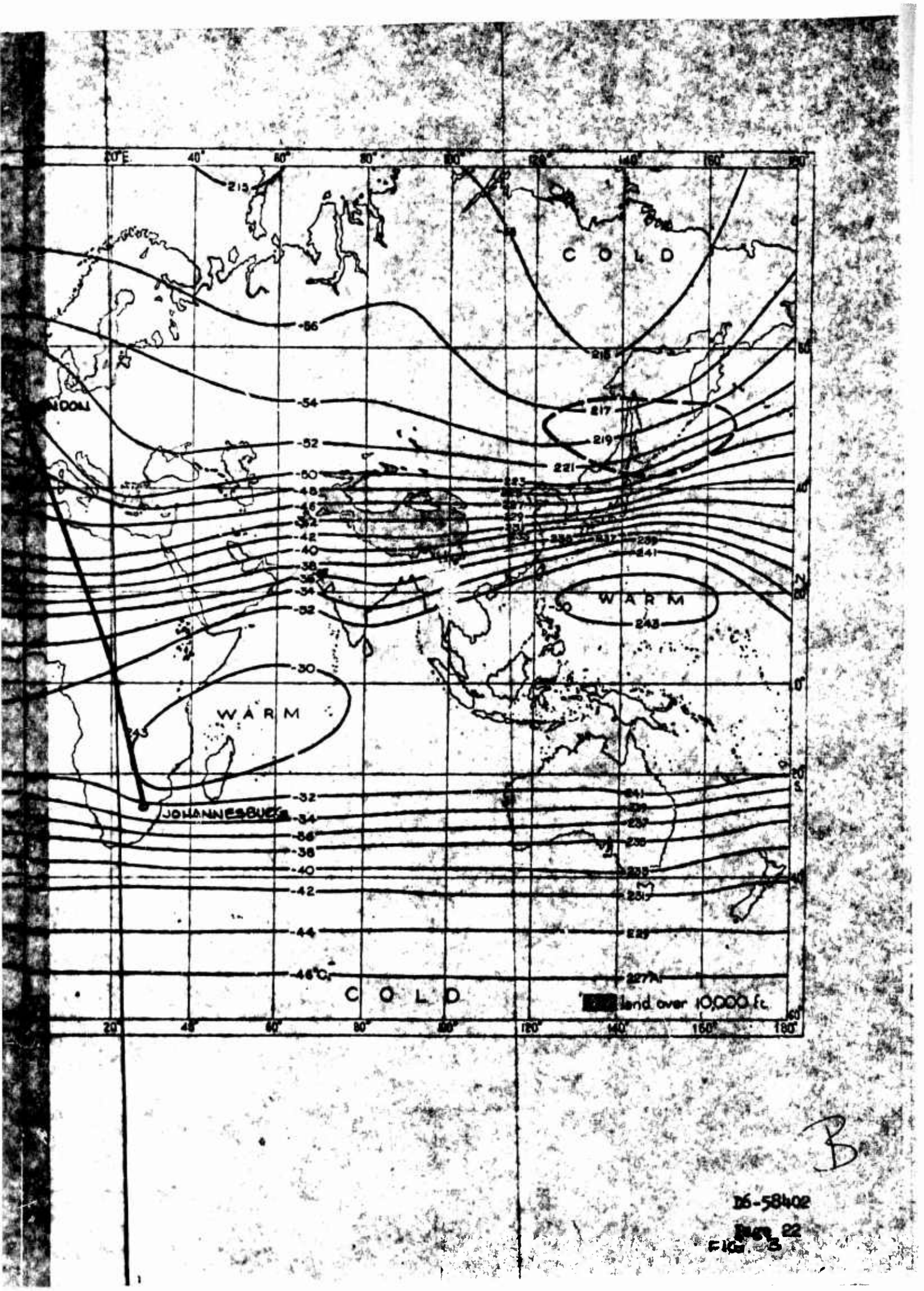


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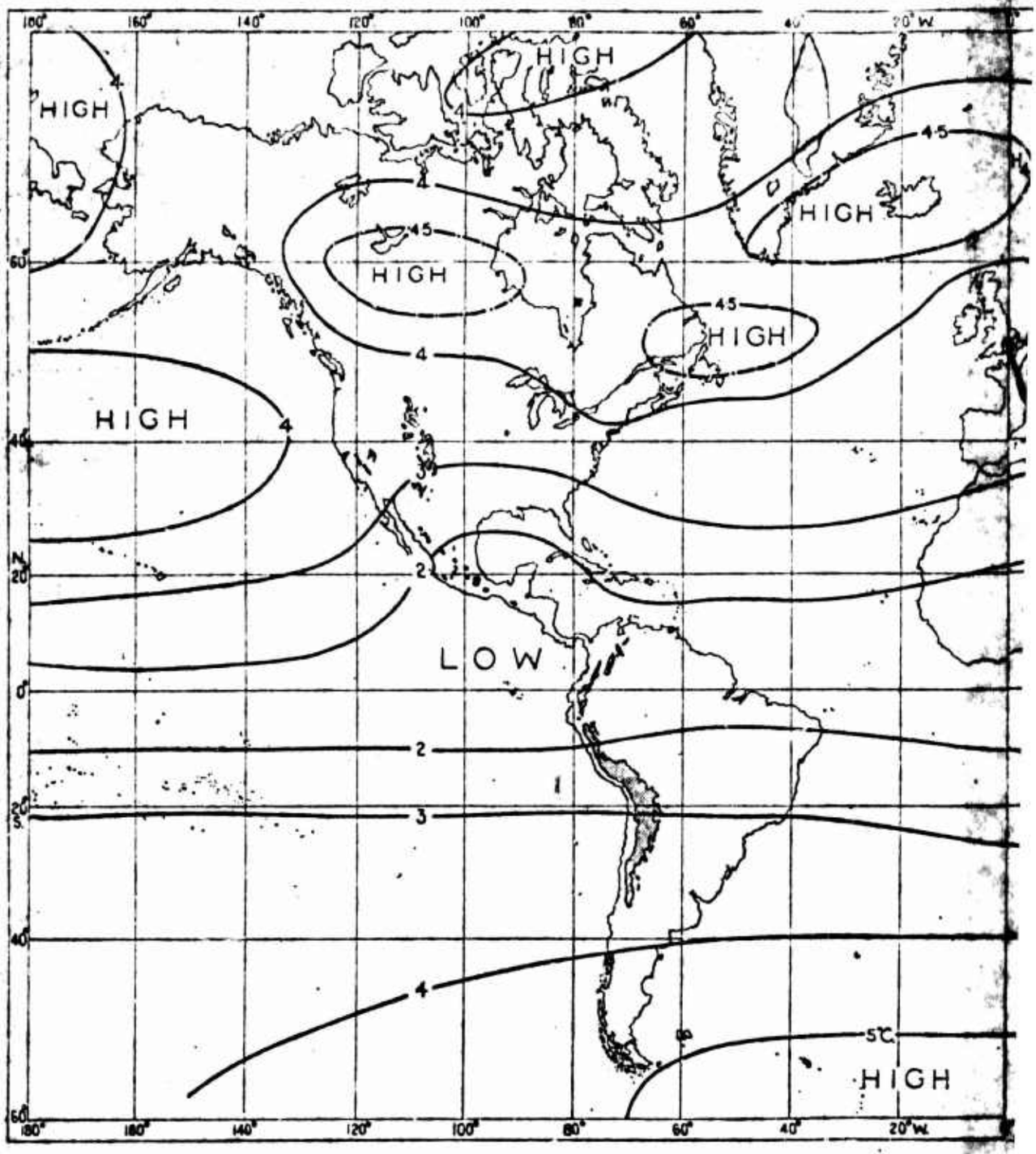
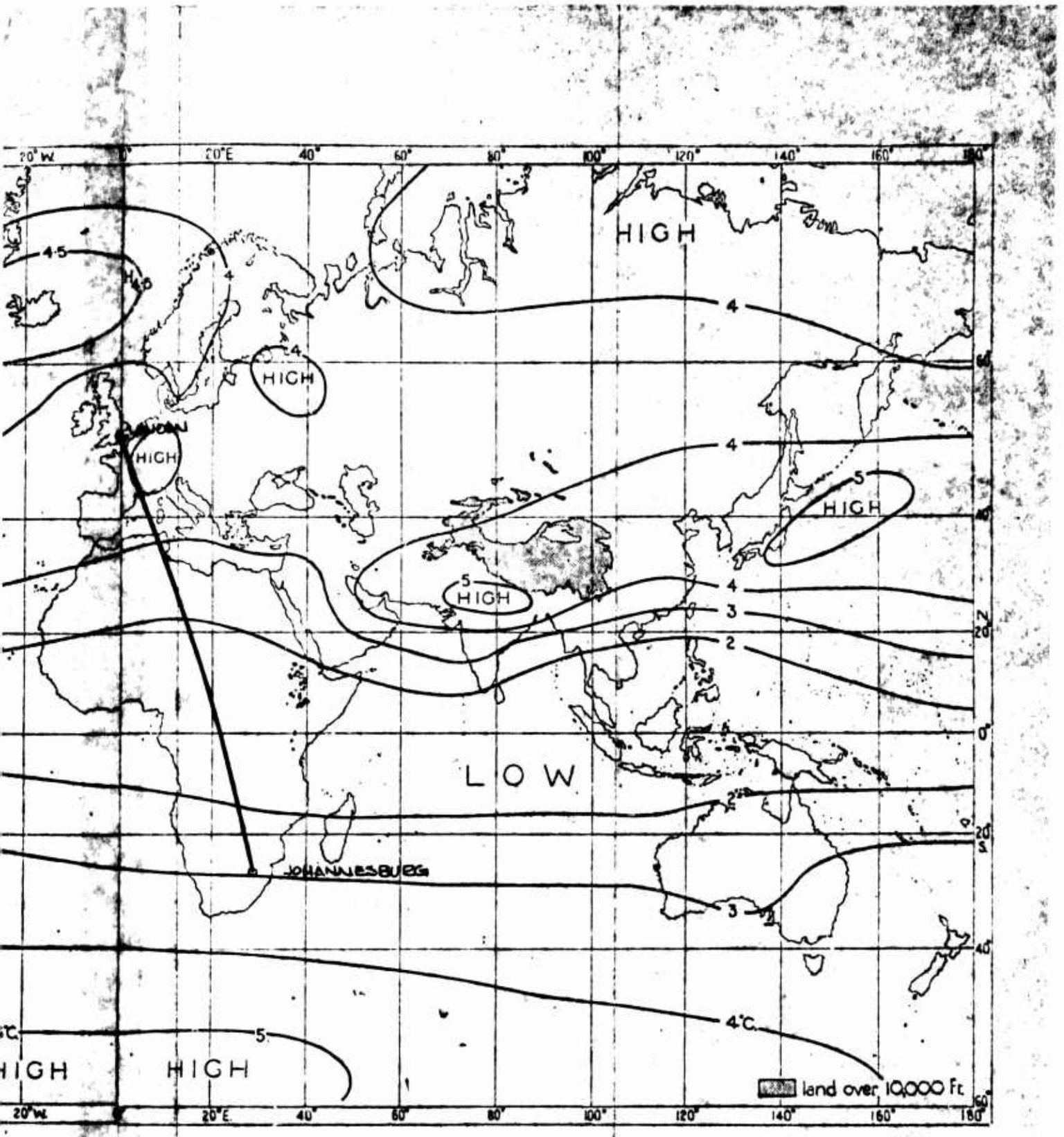
FIG. 3




STANDARD DEVIATION OF TEMPERATURE AT 300 MB. IN JANUARY

UPPER AIR TEMPERATURE OVER THE WORLD

N. GOLDIE, J.G. MOORE AND E.E. AUSTIN




N JANUARY

B

D6-58402

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FIG. 4

CASE NO. 1 OUT OF NROUTE= 1

JOHANNESBURG TO LONDON 4896 N.M.
**********

START POINT LATITUDE = -26.08
LONGITUDE = -28.15
END POINT LATITUDE = 51.24
LONGITUDE = .27

ALTITUDE= 30000FT
**********

MEAN/ST.DEV. FOR POINTS ALONG THE ROUTE *** CELCIUS ***

| DIST N.M. | JANUARY | APRIL | JULY | OCTOBER |
|---|---|---|---|---|
| 0 | -32.7/2.9 | -3[illegible].9/3.1 | -37.8/3.5 | -36.4/3.2 |
| 196 | -31.3/2.6 | -34.5/2.9 | -35.7/3.1 | -35.0/3.0 |
| 392 | -30.2/2.3 | -32.9/2.7 | -33.8/2.8 | -33.7/2.8 |
| 588 | -30.2/2.1 | -32.1/2.5 | -33.4/2.5 | -32.8/2.6 |
| 783 | -30.2/2.0 | -31.3/2.4 | -33.2/2.3 | -32.1/2.4 |
| 979 | -30.4/1.9 | -30.7/2.2 | -33.0/2.2 | -31.4/2.2 |
| 1175 | -30.7/1.7 | -30.2/2.0 | -32.6/2.0 | -30.7/2.1 |
| 1371 | -31.0/1.6 | -29.7/1.8 | -32.3/1.9 | -30.0/2.0 |
| 1567 | -31.5/1.6 | -29.5/1.7 | -32.1/1.8 | -29.6/1.8 |
| 1763 | -32.2/1.6 | -29.4/1.7 | -31.7/1.8 | -29.6/1.8 |
| 1958 | -32.9/1.6 | -29.5/1.6 | -31.4/1.7 | -29.9/1.7 |
| 2154 | -33.7/1.6 | -29.8/1.6 | -31.1/1.8 | -30.5/1.7 |
| 2350 | -34.7/1.6 | -30.3/1.6 | -30.7/1.8 | -31.0/1.7 |
| 2546 | -35.8/1.7 | -31.2/1.7 | -30.3/1.9 | -31.6/1.8 |
| 2742 | -37.7/1.8 | -32.4/1.7 | -29.9/2.0 | -32.4/1.8 |
| 2938 | -39.8/2.0 | -33.8/1.9 | -29.5/2.1 | -33.6/1.9 |
| 3133 | -42.1/2.1 | -35.6/2.1 | -29.5/2.3 | -35.2/1.9 |
| 3329 | -43.6/2.4 | -37.8/2.3 | -30.3/2.5 | -36.8/2.1 |
| 3525 | -44.9/2.7 | -40.2/2.5 | -31.8/2.8 | -38.4/2.3 |
| 3721 | -45.8/2.9 | -42.6/2.9 | -33.9/3.0 | -39.6/2.8 |
| 3917 | -46.7/3.2 | -44.5/3.3 | -35.5/3.1 | -40.5/3.3 |
| 4113 | -47.4/3.4 | -45.4/3.6 | -36.6/3.2 | -41.1/3.9 |
| 4308 | -48.3/3.8 | -46.1/4.0 | -37.7/3.4 | -41.8/4.1 |
| 4504 | -49.1/4.0 | -46.7/4.2 | -38.8/3.5 | -42.6/4.2 |
| 4700 | -49.5/3.9 | -47.1/3.9 | -39.8/3.6 | -43.3/4.0 |
| 4896 | -49.9/3.8 | -47.3/3.7 | -40.7/3.7 | -44.0/4.0 |

TEMPERATURE UNIT IN FOLLOWING TABLES IS *** FAHRENHEIT ***

TEMP. THAT CORRESPOND TO GIVEN PROB. N O T TO BE EXCEEDED

| PROB.VALUE | JANUARY | APRIL | JULY | OCTOBER | ANNUAL |
|---|---|---|---|---|---|
| .50 | -32.3 | -28.7 | -27.1 | -29.0 | -28.8 |
| .75 | -24.9 | -22.9 | -23.1 | -23.7 | -23.6 |
| .85 | -22.6 | -20.9 | -21.3 | -21.6 | -21.5 |

FIT A NORMAL CURVE TO THE ROUTE DISTR.

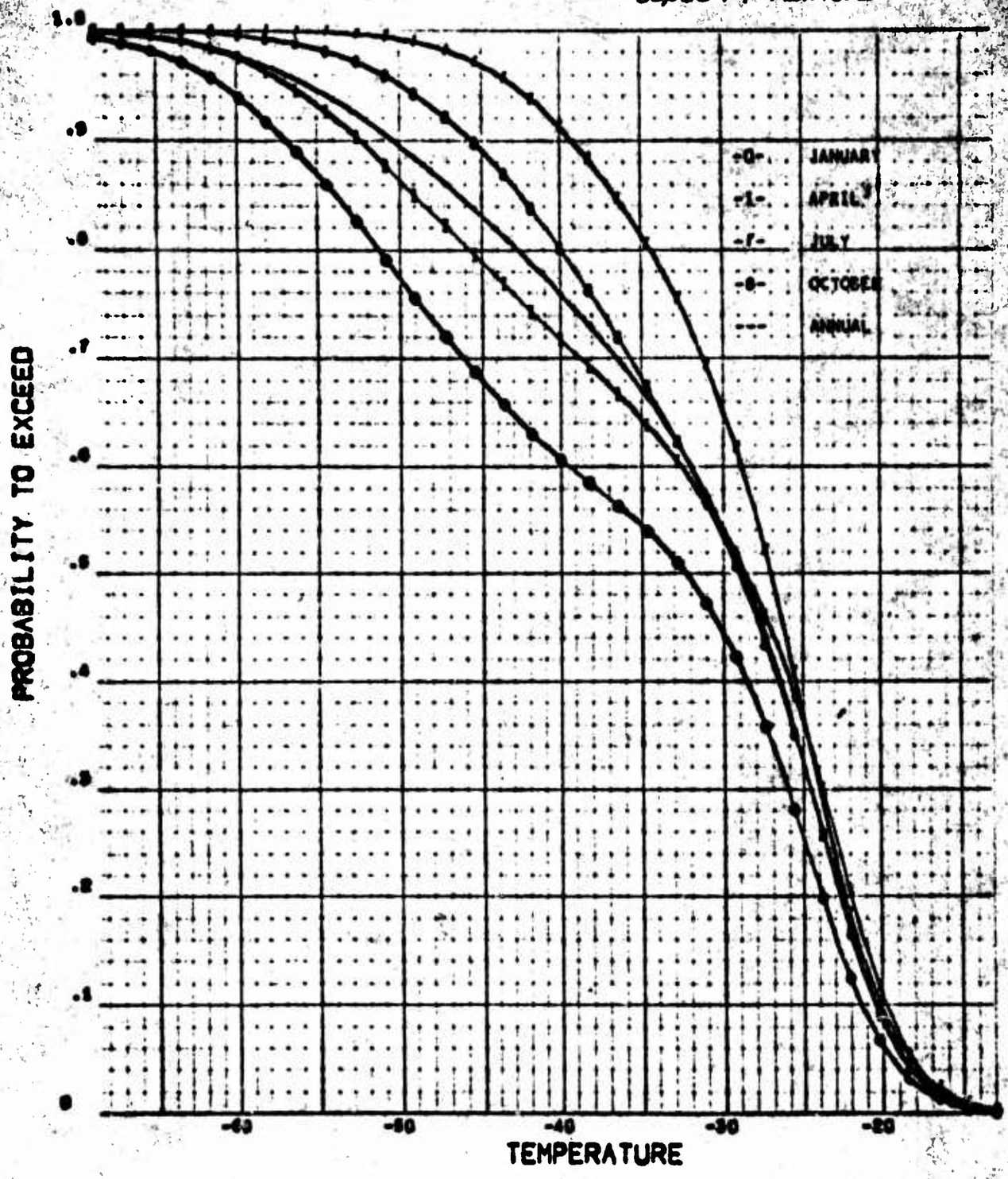
| | JANUARY | APRIL | JULY | OCTOBER | ANNUAL |
|---|---|---|---|---|---|
| MEAN TEMP= | -36.11 | -32.06 | -27.95 | -30.61 | -31.40 |
| ST. DEV. = | 13.33 | 11.70 | 7.30 | 9.41 | 10.86 |

RESEMBLANCE OF FITTED CURVE TO ROUTE DISTR.
DEVIATION IN PROBABILITY VALUES FOR CALC. TEMPERATURES

| | | | | | |
|---|---|---|---|---|---|
| ARIT.MEDIAN DEV.= | .036 | .034 | .012 | .019 | .029 |
| MAXIMUM DEV. = | .12[illegible] | .114 | .059 | .068 | .096 |

Figure 5

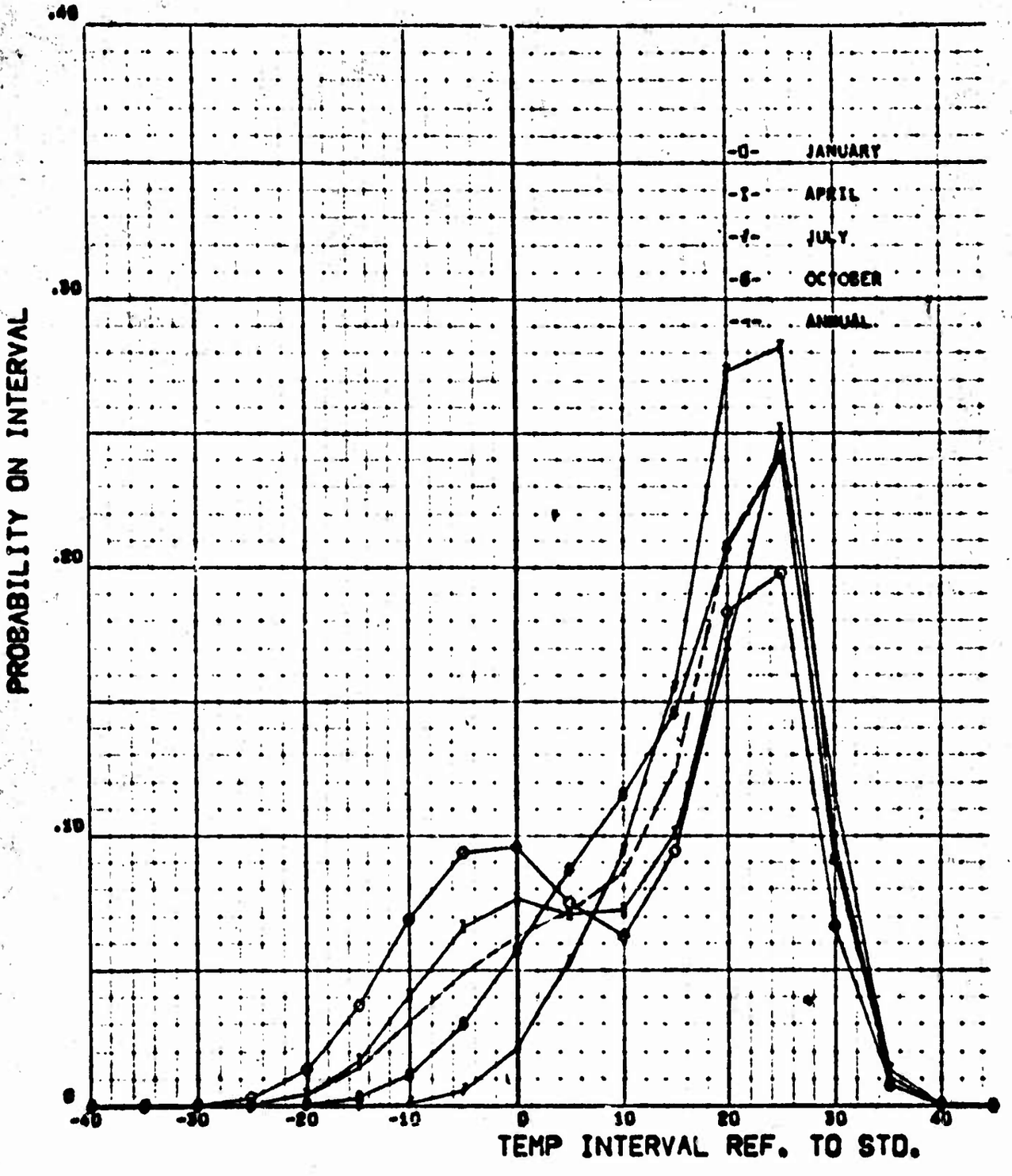
JOHANNESBURG TO LONDON
30,000 FT ALTITUDE



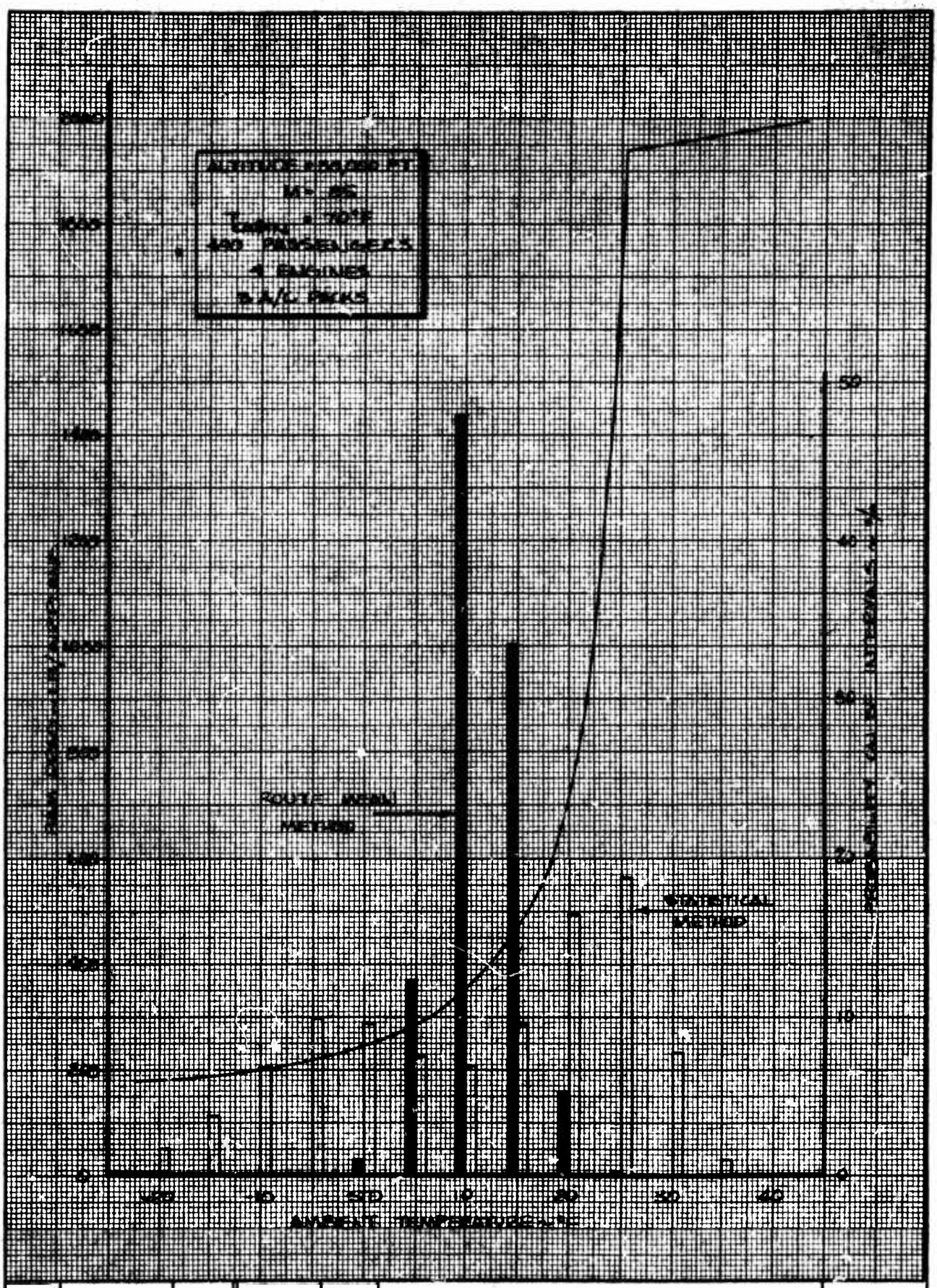

| | | | | | |
|---|---|---|---|---|---|
| CHK | | | | | SEASONAL AND ANNUAL DISTR. FOR GIVEN ALT. AND ROUTE |
| SKTCH | | | | | |
| APPD | | | | | |
| APPD | | | | | |
| | | | | | BOEING |

FIG. 6
D6-58402
25

JOHANNESBURG TO LONDON
50,000 FT ALTITUDE




| | | | | | |
|---|---|---|---|---|---|
| CALC | | | REVISED | DATE | PROBABILITY ON INTERVALS OF SPECIFIED WIDTH |
| CHECK | | | | | FIG. 7 |
| APPR | | | | | D6-58402 |
| APPR | | | | | |
| | | | BOEING | | 26 |




| | | | | | |
|---|---|---|---|---|---|
| CALC | | | REVISED | DATE | 747 AIR CONDITIONING PACK RAM AIR DRAG WITH ROUTE TEMPERATURE DISTRIBUTION |
| CHECK | | | | | |
| APR | | | | | |
| APR | | | | | |
| Dm | D.B | | | | THE BOEING COMPANY |

FIG. 8

D6-58402

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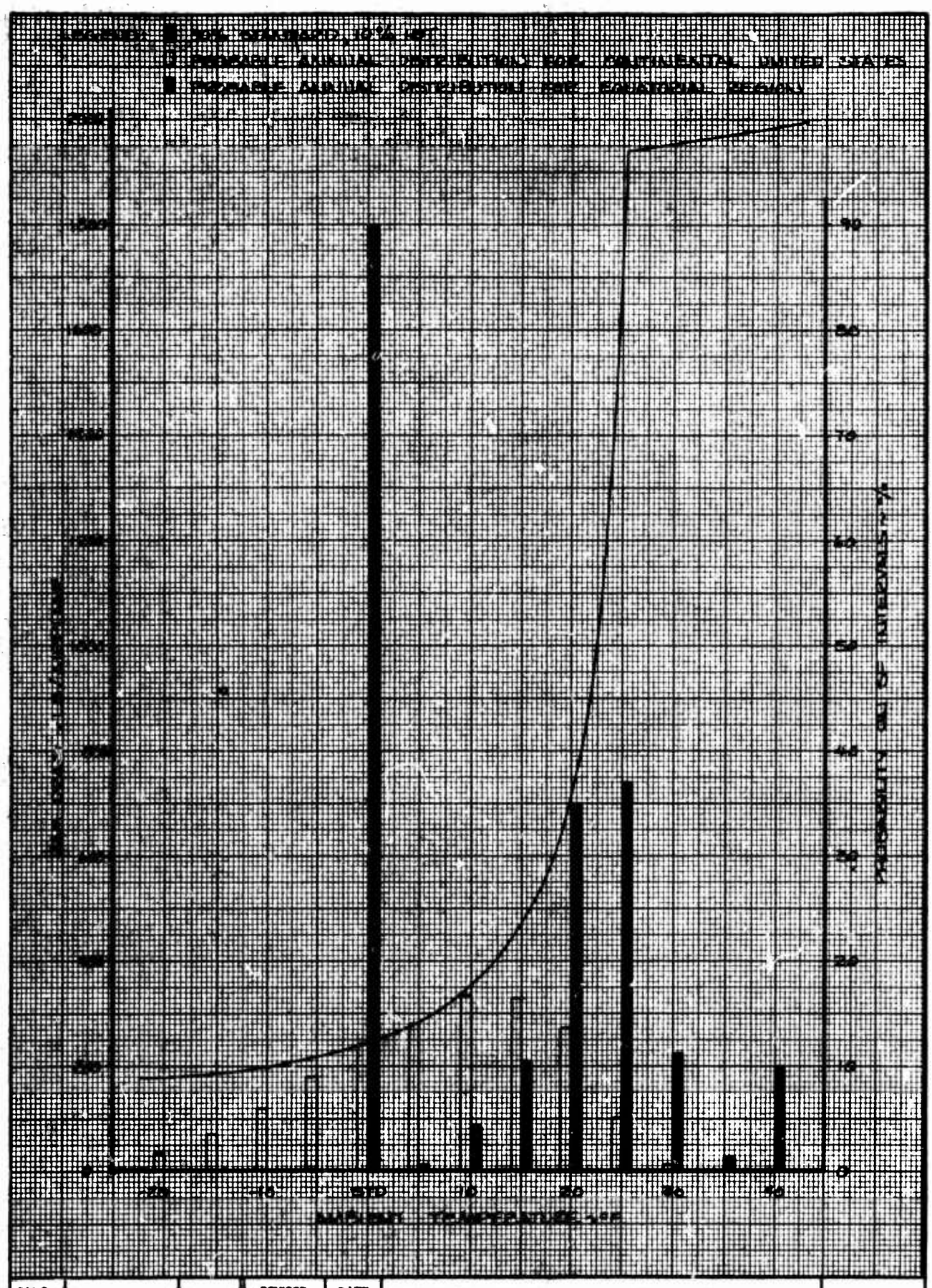
K+E ALBANENE 1961 TRACING PAPER




| | | | | | | |
|---|---|---|---|---|---|---|
| CALC | | | REVISED | DATE | 747 AIR CONDITIONING PACK RAM AIR DRAG WITH REGIONAL TEMPERATURE DISTRIBUTION | FIG. 9 |
| CHECK | | | | | | D6-58402 |
| APR | | | | | | |
| APR | | | | | | |
| Drn | DLB | | | | THE BOEING COMPANY | PAGE 28 |

TD 461 C-84

K+E ALBANENE 1661 TRACING PAPER

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2. Document D6-6833TN, Enroute Temperatures, L. A. Rasmussen, Dec. 1963.
3. Mathematical Handbook for Scientists and Engineers, Korn and Korn, Mc-Graw Hill Company, AIR 005471.
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5. U. S. Standard Atmosphere, 1962.
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## APPENDIX A

## USE OF THE AVAILABLE METEOROLOGICAL DATA TO GENERATE REGIONAL TEMPERATURE DISTRIBUTIONS

The concepts of Standard, Hot and Cold Atmosphere (References 5 through 7) are commonly combined to designate a probable temperature distribution for trade studies or performance calculations on the typical operation condition of an airplane system being studied. Any such combination of the standardized atmospheres (i.e., 90 percent of the time at Standard Day and remaining 10 percent at Hot Day) is likely to involve a substantial degree of idealization of any probable temperature distribution and the risk for misinterpretations becomes apparent. If Standard Day condition is encountered during the major part of the time, as in above example, the probability of experiencing Hot Day is extremely remote. On the other hand, if the interest is focused on the localized areas where Hot Day temperature actually is being exceeded the specified percentage of the time, it is improbable that temperatures as low as Standard Day will be encountered.

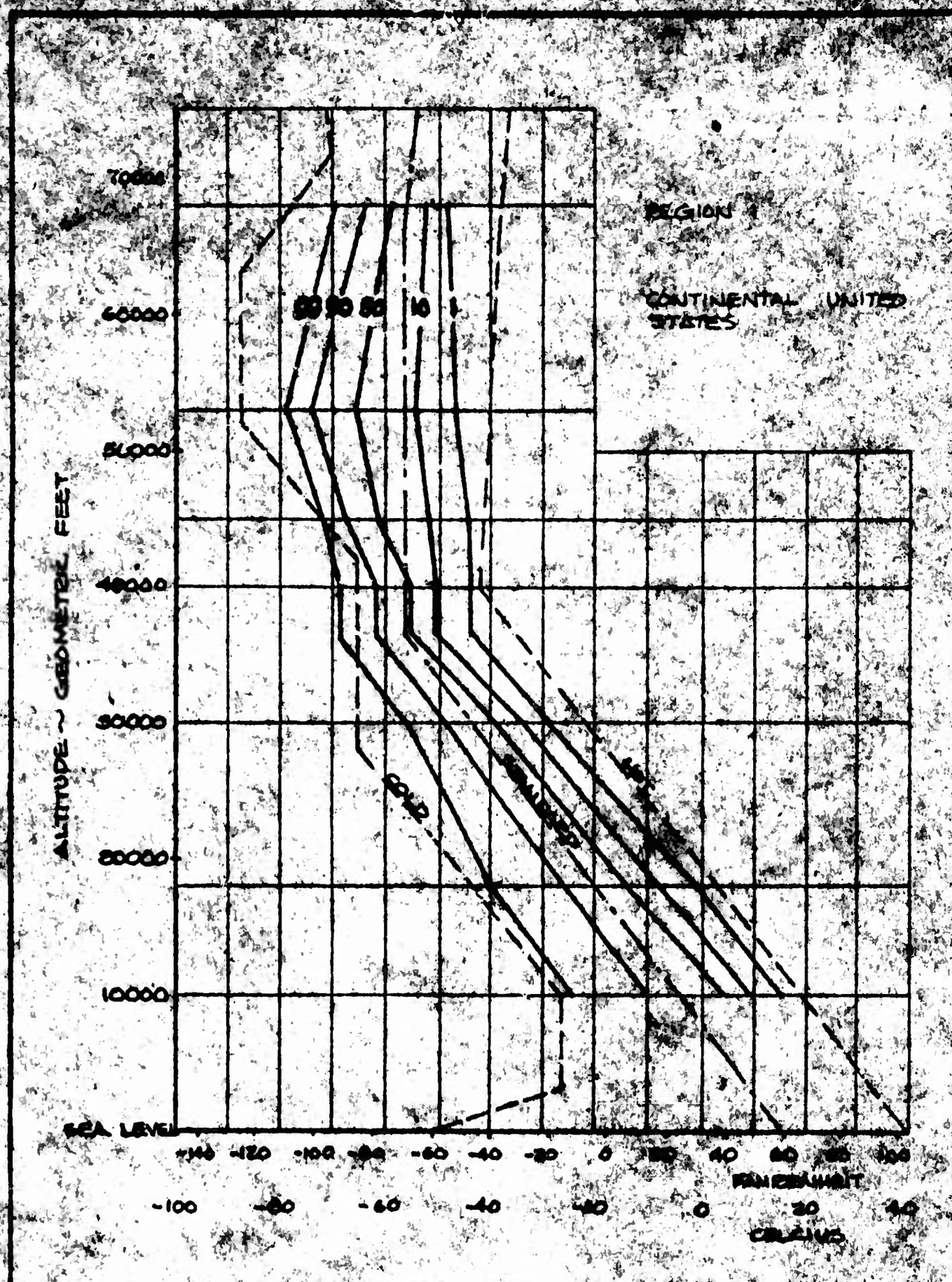
Using the available meteorological data, it is possible to generate a more realistic temperature distribution curve applicable to a specified region of the earth, thereby eliminating the uncertainties inherent in the use of the standardized atmospheres. The developed data becomes applicable to an airplane in traffic of about equal density over the specified region. Data for four regions of common interest has been generated. These are:

1. Continental United States with adjacent border areas (52.5N to 22.5N latitude and 65W to 125 W longitude).
2. Area 1 combined with North Atlantic, Central and Southern Europe (Area 1 plus 62.5N to 37.5N latitude and 25E to 65W longitude).
3. Polar region of Northern Hemisphere (90N to 62.5N latitude).
4. Equatorial region (22.5N to 22.5S latitude).

Data pertinent to any other region of the earth of interest can, upon request, be generated.

Figures 10 through 13 give the temperatures that are probable to be exceeded 99, 90, 50, 10 and 1 percent of the year over the different specified regions. The three standardized atmospheres (Standard, Hot and Cold) are superposed for comparison and reference. The temperatures at the different levels where calculations have been carried out (10,000, 18,000, 30,000, 40,000, 45,000, 53,000 and 68,000 feet) are interconnected in the most probable way.

Figures 14 through 17 give the complete seasonal and annual (arithmetic mean of the four seasons) temperature distribution at 30,000 ft. altitude. Similar curves can be made available for any region and altitude. Figure 18 is a summary table of data from Figures 10 through 13, everything being referred to Standard Day condition at each altitude.

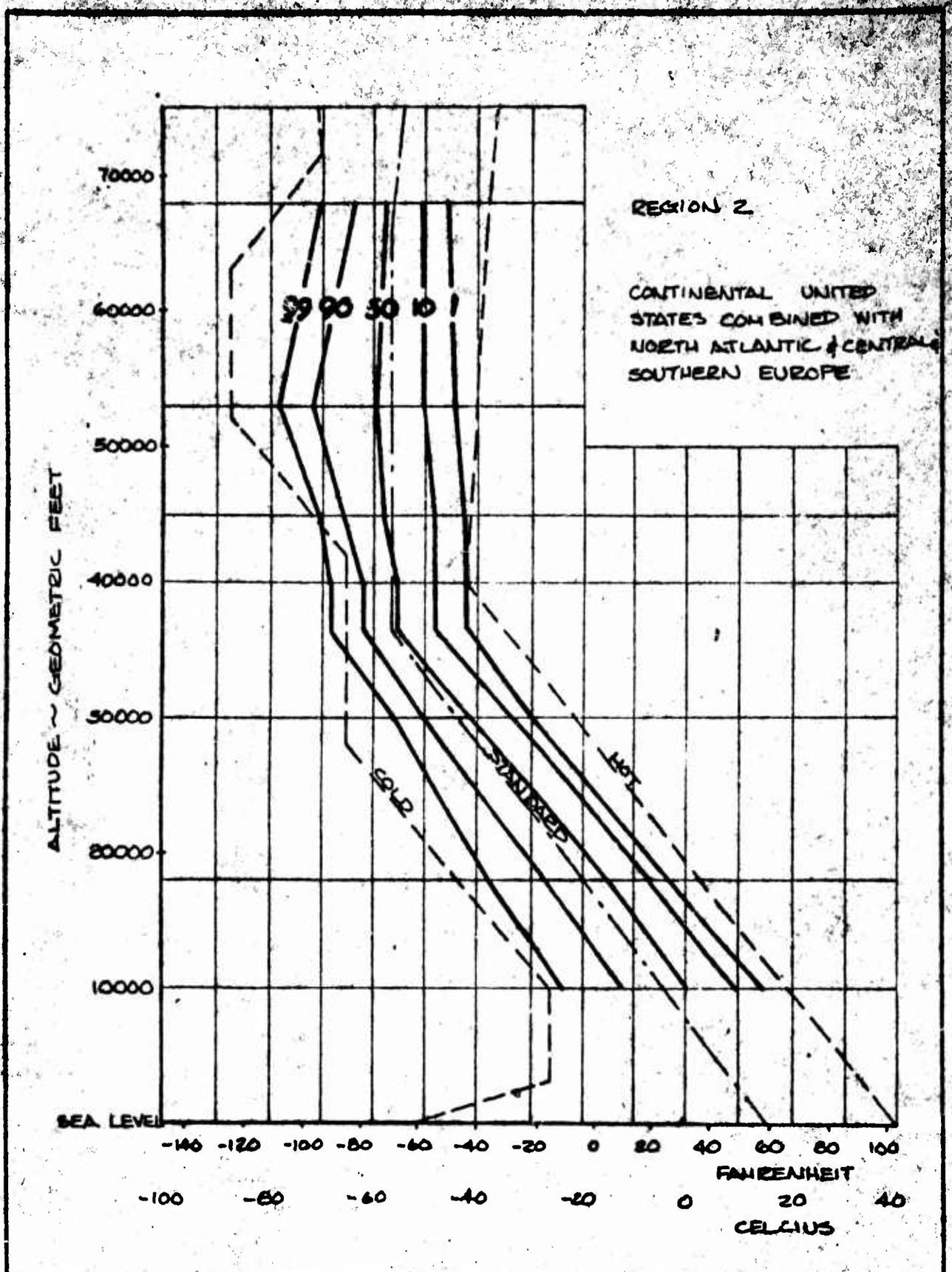



| | | | REVISED | DATE |
|---|---|---|---|---|
| CALC | | | | |
| CHECK | | | | |
| APPD | | | | |
| APPD | | | | |
| | | | | |

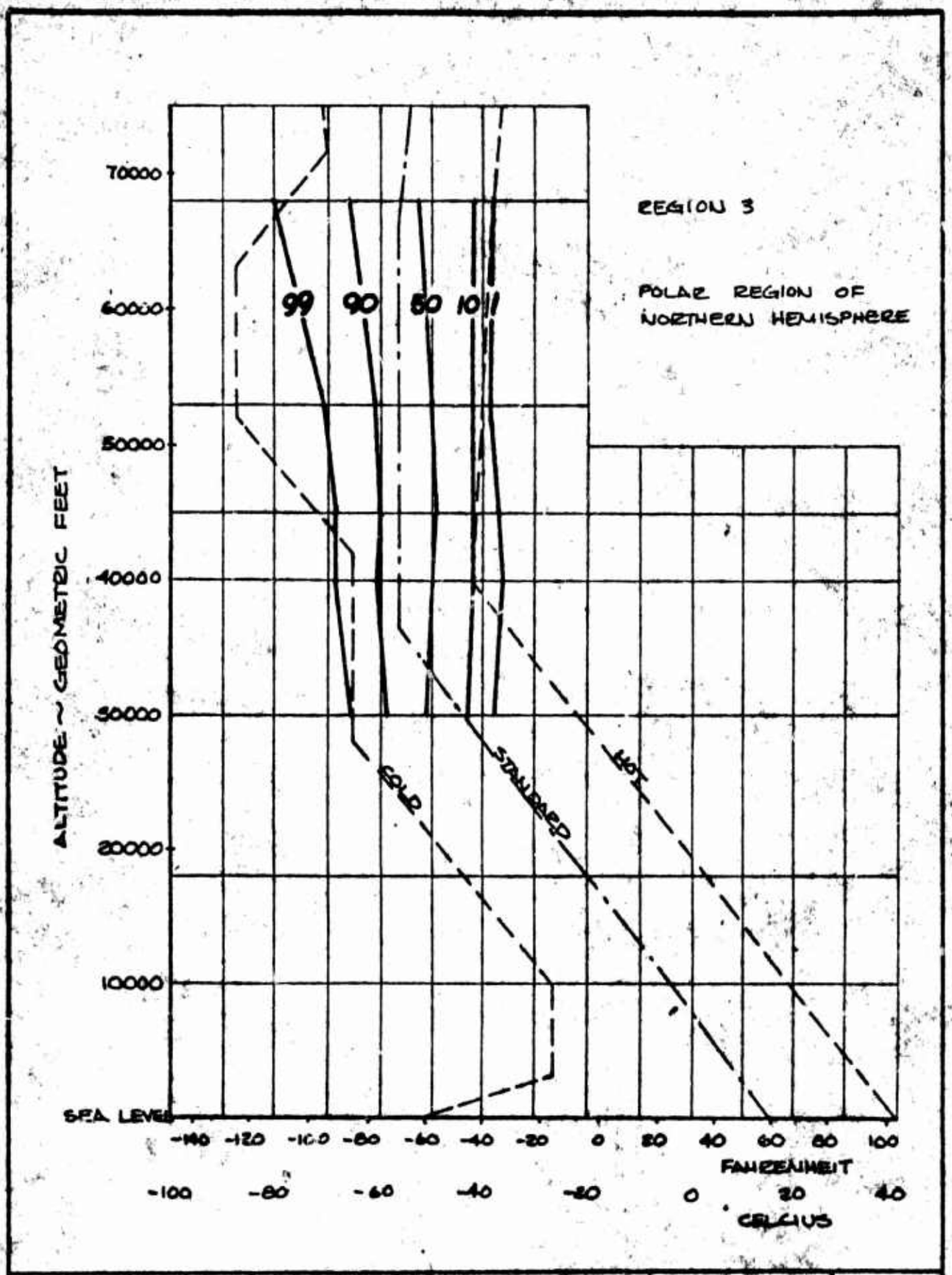
99, 90, 50, 10 AND 1 PER CENT PROBABILITY OF EXCEEDED, JG, TEMPERATURE

FIG: 10

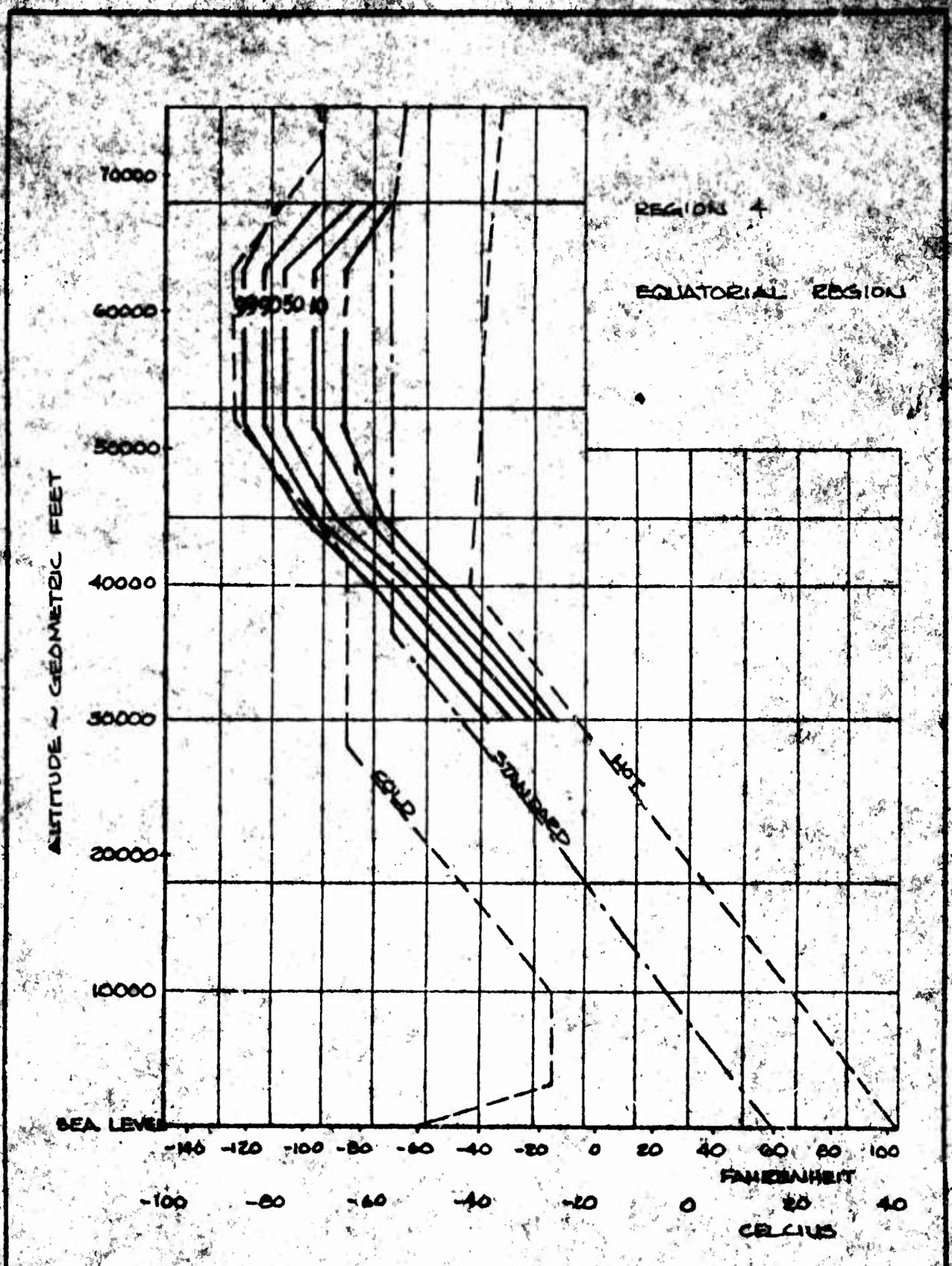
THE COMPANY




| | | | | | | |
|---|---|---|---|---|---|---|
| CALC | | | REVISED | DATE | 99, 90, 50, 10 AND 1 PER CENT PROBABILITY OF EXCEEDING, TEMPERATURE | FIG. 11 |
| CHECK | | | | | | D6-58402 |
| APPD | | | | | THE BOEING COMPANY RENTON, WASHINGTON | PAGE 33 |
| APPD | | | | | | |




| | | | | | | |
|---|---|---|---|---|---|---|
| CALC | | | REVISED | DATE | 99,90,50,10 AND 1 PER CENT PROBABILITY OF EXCEEDING, TEMPERATURE | FIG. 12 |
| CHECK | | | | | | |
| APPR. | | | | | | D6-58402 |
| APPD | | | | | THE BOEING COMPANY RENTON, WASHINGTON | PAGE 34 |




| | | | | | |
|---|---|---|---|---|---|
| CALC. | | | REVISED | DATE | 99, 90, 50, 10 AND 1 PER CENT PROBABILITY OF EXCEEDING, TEMPERATURE |
| CHECK | | | | | |
| APPD | | | | | |
| APPD | | | | | |
| | | | | | |

FIG. 13
D6-58402
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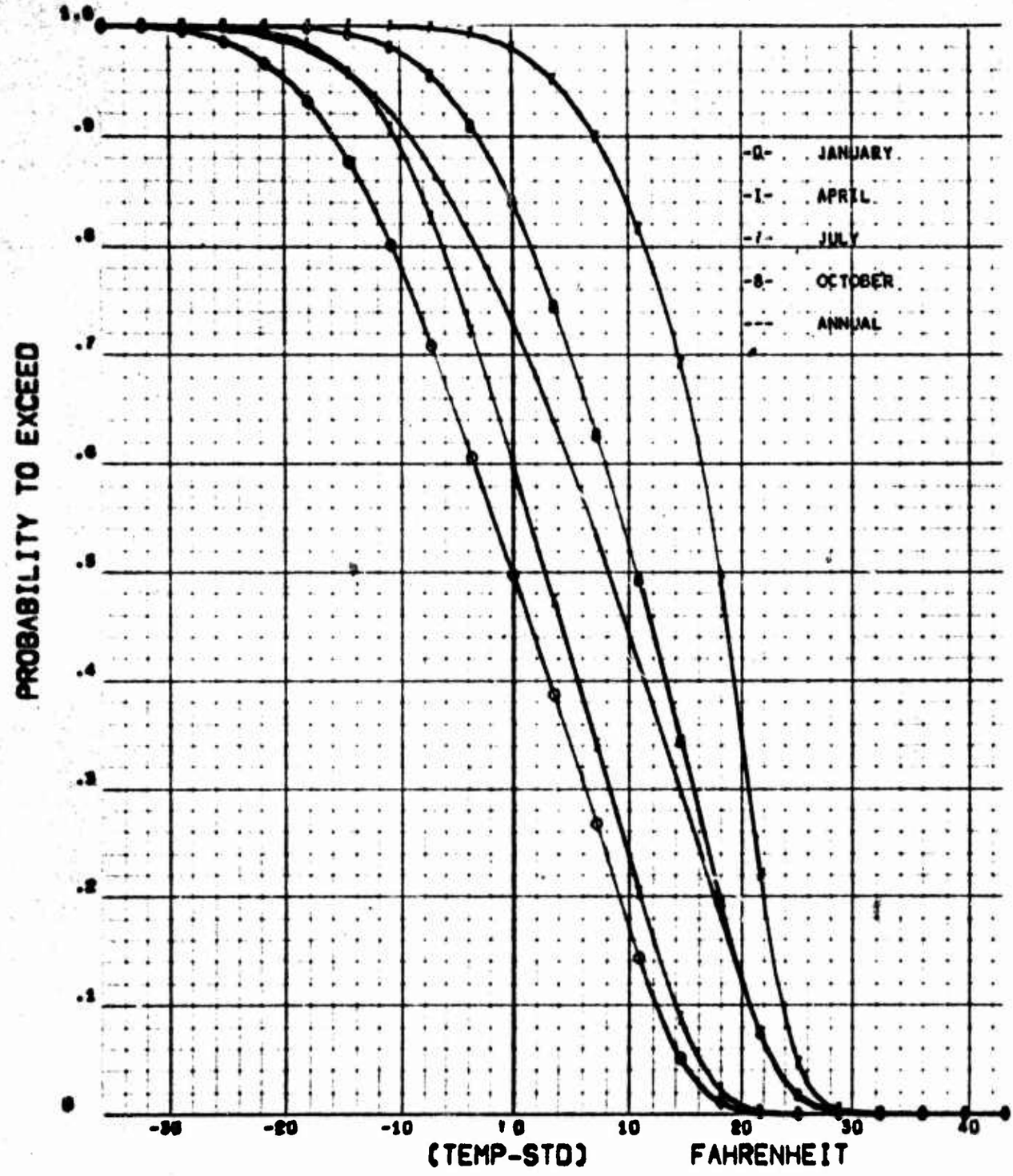
THE BOEING COMPANY
RENTON, WASHINGTON

CONTINENTAL UNITED STATES
30,000 FT ALTITUDE

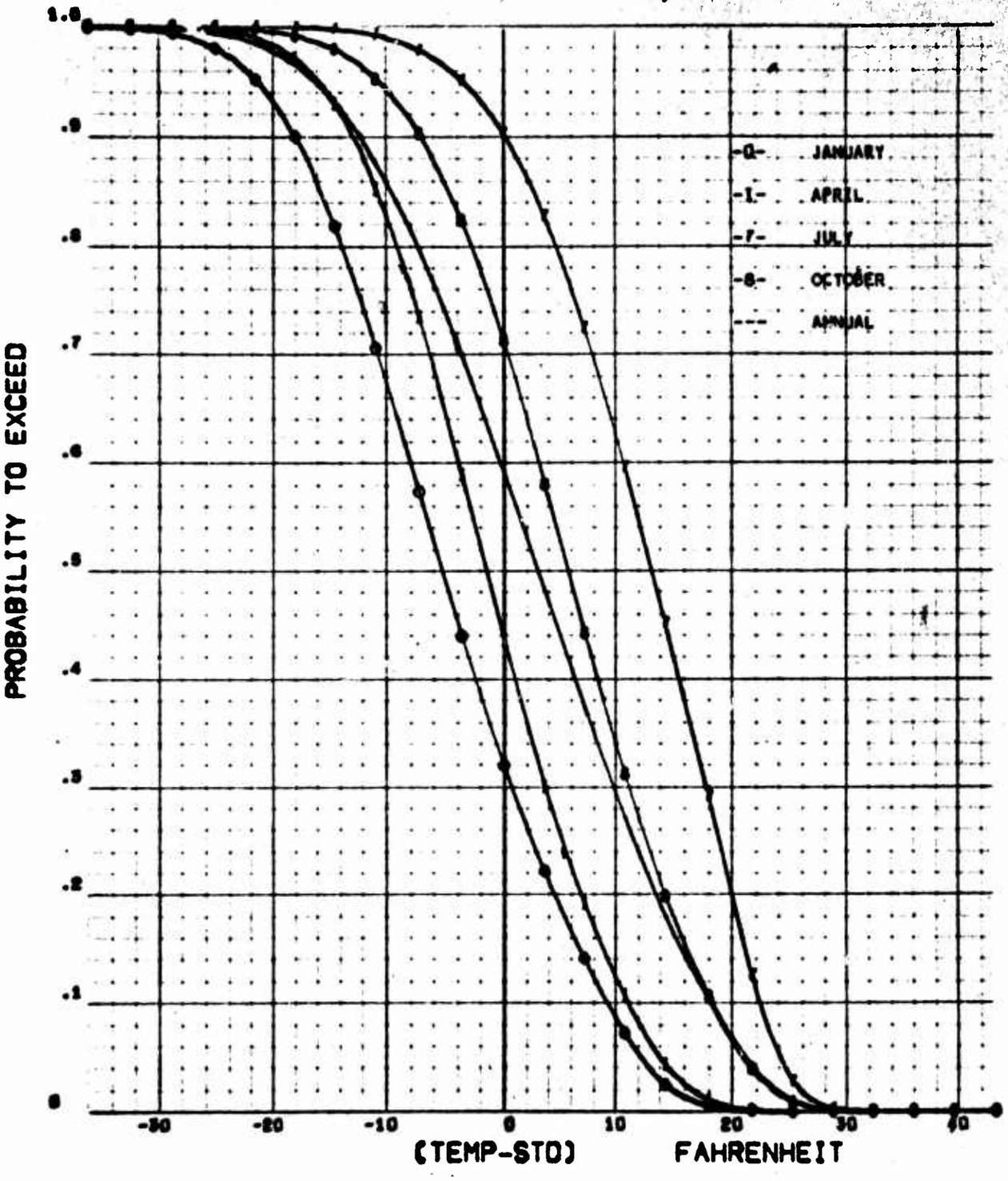



| | | | | | |
|---|---|---|---|---|---|
| CALC | | | REVISED | DATE | SEASONAL AND ANNUAL DISTR. FOR SPEC. GEOGR. AREA |
| CHECK | | | | | |
| APPD | | | | | |
| APPD | | | | | |
| | | | | | THE BOEING COMPANY |

FIG. 14

D6-58402

CONTINENTAL UNITED STATES
COMBINED WITH NORTH ATLANTIC
CENTRAL & SOUTHERN EUROPE
39000 FT ALTITUDE




| | | | | | |
|---|---|---|---|---|---|
| CALC | | | REVISED | DATE | SEASONAL AND ANNUAL DISTR. FOR SPEC. GEOGR. AREA |
| CHECK | | | | | |
| APPD | | | | | |
| APPD | | | | | |
| | | | | | THE BOEING COMPANY RENTON, WASHINGTON |

FIG. 15
D6-58402
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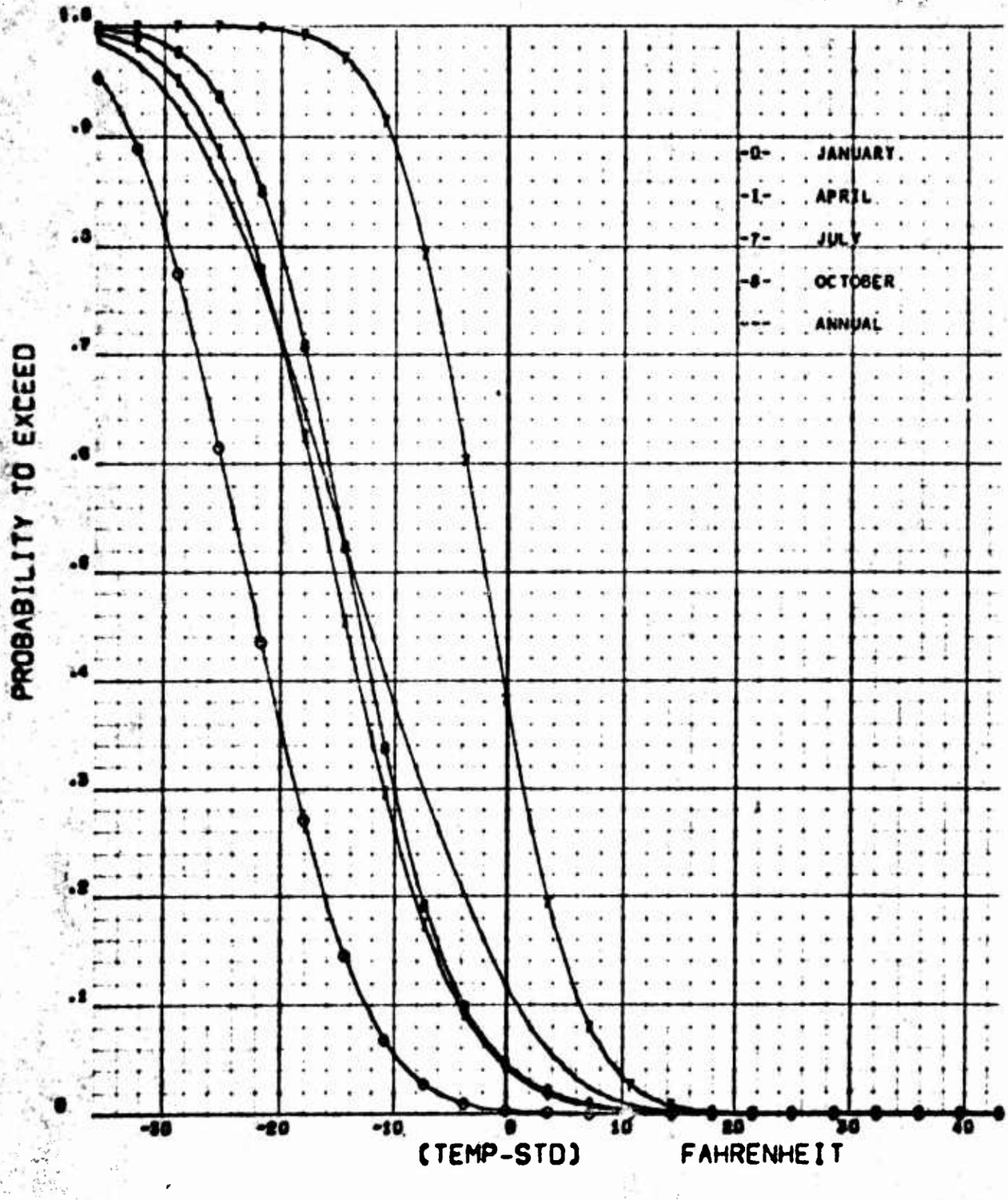
POLAR REGION
30,000 FT




| | | | | | |
|---|---|---|---|---|---|
| CALC | | | REVISED | DATE | SEASONAL AND ANNUAL DISTR. FOR SPEC. GEOGR. AREA |
| CHKD | | | | | |
| APPD | | | | | |
| APPD | | | | | |
| | | | | | THE BOEING COMPANY |

FIG. 16

D6-58402

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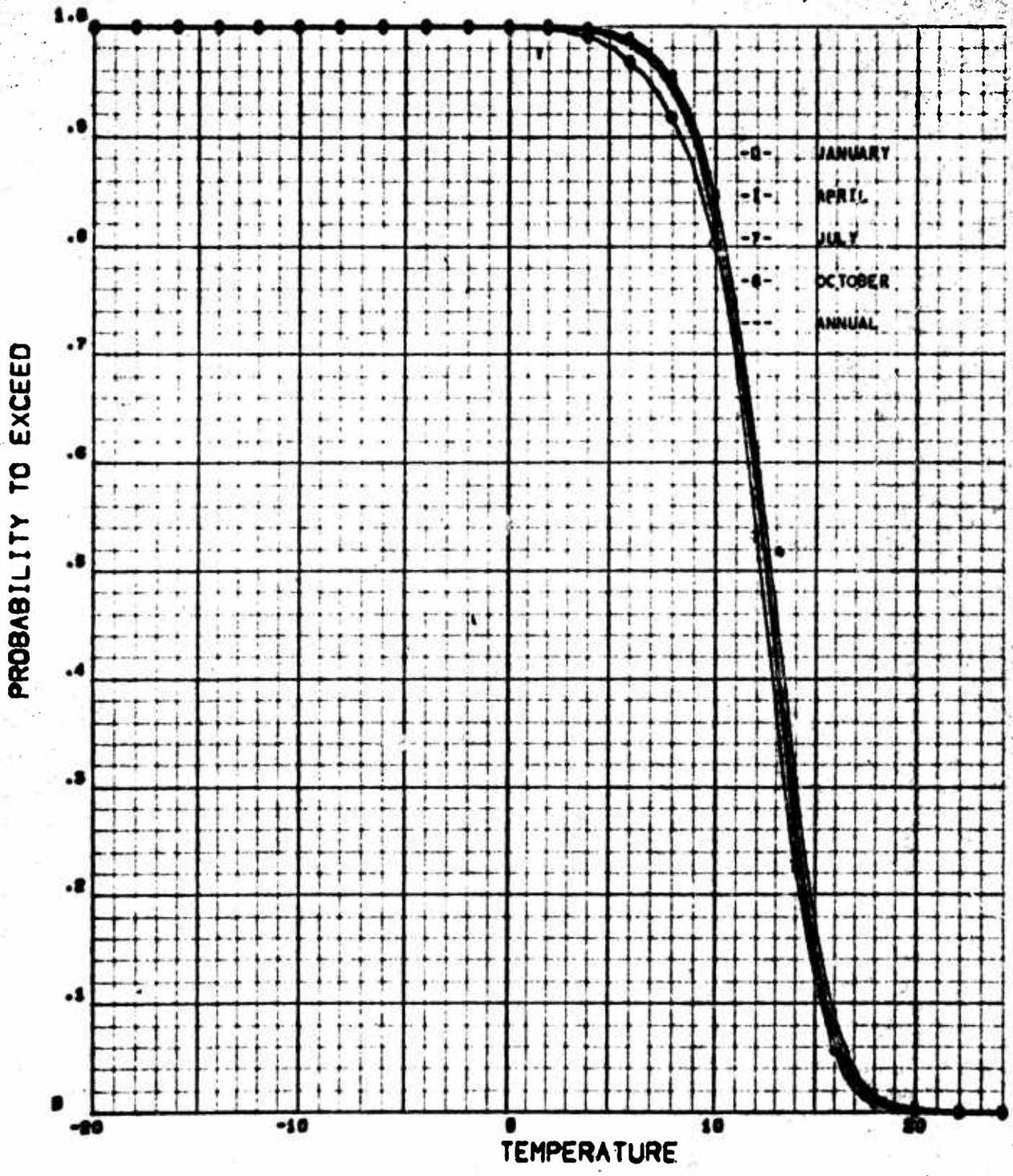
EQUATORIAL REGION
30,000 FT




| | | | | | | |
|---|---|---|---|---|---|---|
| CALC | | | REVISED | DATE | SEASONAL AND ANNUAL DISTR. FOR SPEC. GEOGR. AREA | FIG. 17 |
| CHECK | | | | | | D6-58402 |
| APPD. | | | | | THE BOEING COMPANY | PAGE 39 |

| ALTITUDE | STANDARDIZED EXTREMES COLD | HOT | REGION | TEMPERATURE TO BE EXCEEDED ON A YEAR ROUND BASIS ~ FAHRENHEIT 99% | 90% | 50% | 10% | 1% |
|---|---|---|---|---|---|---|---|---|
| 10,000 | -38 | 43 | 1 | -35 | -10 | 16 | 28 | 36 |
| | | | 2 | -36 | -15 | 8 | 25 | 33 |
| 18,000 | -34 | 41 | 1 | -29 | -8 | 15 | 28 | 31 |
| | | | 2 | -33 | -10 | 8 | 24 | 29 |
| 30,000 | -35 | 40 | 1 | -21 | -9 | 8 | 21 | 27 |
| | | | 2 | -23 | -12 | 5 | 18 | 24 |
| | | | 3 | -37 | -27 | -14 | 0 | 9 |
| | | | 4 | 9 | 16 | 22 | 28 | 33 |
| 40,000 | -15 | 25 | 1 | -20 | -9 | 1 | 11 | 22 |
| | | | 2 | -22 | -10 | 2 | 11 | 26 |
| | | | 3 | -21 | -7 | 11 | 26 | 36 |
| | | | 4 | -7 | -1 | 5 | 12 | 18 |
| 45000 | -29 | 27 | 1 | -26 | -20 | -8 | 8 | 20 |
| | | | 2 | -25 | -18 | -2 | 14 | 25 |
| | | | 3 | -20 | -6 | 13 | 26 | 84 |
| | | | 4 | -31 | -25 | -18 | -9 | -2 |
| 53,000 | -55 | 40 | 1 | ~-38 | -31 | -16 | 4 | 16 |
| | | | 2 | ~-37 | -27 | -5 | 11 | 22 |
| | | | 3 | -25 | -8 | 12 | 27 | 33 |
| | | | 4 | -53 | -46 | -36 | -26 | -14 |
| 68,000 | -37 | 32 | 1 | -23 | -15 | -4 | 7 | 13 |
| | | | 2 | -25 | -14 | -2 | 10 | 19 |
| | | | 3 | ~-38 | -21 | 8 | 26 | 32 |
| | | | 4 | ~-37 | -25 | -14 | -6 | 0 |

LEGEND: DATA APPEAR ON EACH ALTITUDE AND FOR EACH PROBABILITY LEVEL AS:

REGION 1 U.S.
REGION 2 U.S. & N.A. +E.
REGION 3 POLAR
REGION 4 EQUATOR

| CALC | | | REVISED | DATE | TEMPERATURES REFERRED TO STANDARD ATMOSPHERE | FIG. 18 |
|---|---|---|---|---|---|---|
| CHECK | | | | | | D6-58402 |
| APR | | | | | THE BOEING COMPANY | PAGE 40 |
| APR | | | | | | |
| DRA | | | | | | |

```
      PROGRAM AVO1(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2,
     1TAPE8)

C MAIN PROGRAM, INPUT, OUTPUT

      COMMON A,TNMP,STDN,LM3,DIST,ITHI,ITLO,ITR,MTH,PROB,TPR,REV,
     1TMN,SCALC,USSA,PRI,PINV,TIM,NINT,DEGR,LALT,ISSS,EMAX,EAVR
      DIMENSION A(11,7,4,2),TNMP(57,4,2),STDN(57,4,2),DIST(57),
     1PROB(70,5),TPR(3,5),TMN(5),SCALC(5),USSA(5),PRI(30,5),
     2PINV(30,5),TIM(30),DEGR(70),LALT(5),EMAX(5),EAVR(5)
      DIMENSION SEASON(4),GLAT(2),GLNG(2),TML(57,4),
     1TSDL(57,4),PRV(3),PNE(3),PROD(70),PIOD(30),UNIT(2),DEGA(70)
      INTEGER OPT(3),ALTI(2)

      CCF(TC)= 1.8*(TC+40.)-40.

C ALL TEMPERATURE INPUTS IN CELCIUS(EXCEPT TINT, WHICH IS OPTIONAL)
C  INPUT NUMBER OF ALTITUDES AND HEIGHT IN FEET (IN ORDER OF
C   INCREASING ALTITUDES)

      READ 130, NALT,(ALTI(I),I=1,NALT)

C INPUT OPTIONS FOR CALCULATIONS
C      OPT(1)=1 IF PRINTING OF ALL OUTPUT DATA DESIRED, =0 IF NOT
C      OPT(2)=1 IF TEMP. OUTPUT IN FAHRENHEIT, =2 IF CELCIUS
C      OPT(3)=1 IF PROBABILITIES ON TEMP. INTERVALS DESIRED, =0 IF NOT
C      TINT= SPECIFY DESIRED WIDTH OF TEMP INTERVALS (REAL). CAN BE
C      OMITTED IF OPT(3)=0. OPT(2) CONTROLS UNIT OF TEMP.

      READ 130,(OPT(IB),IB=1,3),TINT
      IF (OPT(2).EQ.1) TINT= TINT/1.8

C PRINT HEADING

      PRINT 150
      PRINT 160,(OPT(IB),IB=1,3)

C  MOVE REQUIRED METEOROLOGICAL DATA FROM STORAGE TAPE TO MEMORY

      DO 200 LX=1,NALT
  190 READ (8) LALT(LX),USSA(LX)
```

APPENDIX B

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Page 41

```
      READ (8) ((ALLOC,MTH,LX),LOC=1,1117),MTH=1,4)
      IF (LALT(LX).EQ.ALTI(LX)) 200,190
  200 CONTINUE

C INPUT NUMBER OF ROUTES AND A LABLE CARD FOR EACH ROUTE

      READ 130,NROUTE
      DO 3000 NCASE=1,NROUTE
      READ 260
      PRINT 270,NCASE,NROUTE
      PRINT 260
      PRINT 275

C INPUT GEOGRAPHICAL LOCATION OF START AND END POINT OF ROUTE

      READ 290, (GLAT(I),GLNG(I),I=1,2)
      I55S= 0
      CALL TEMP(GLAT,GLNG,NALT)

C TEMP FURNISHES TEMP.MEAN AND ST.DEV FOR POINTS ABOUT 200N.M. APART
C ALONG THE ROUTE ON ALL SEASONS AND ALTITUDES

      DO 2000 LVL=1,NALT

      IF (I55S.NE.0) GO TO 2000
      IF (LVL.EQ.1) 1360,1390
 1360 PRINT 1380, (GLAT(I),GLNG(I),I=1,2)
 1390 PRINT 1400, LALT(LVL)

C FIND TEMP.RANGE TO BE USED IN CALC. ON EACH PARTICULAR ALTITUDE
C TRANSFORM MEAN-.AND ST.DEV. INTO 2-DIM. ARRAYS

      TMIN= TNMP(1,1,LVL)
      TMAX= TMIN
      DO 360 IB=1,4
      DO 360 IA=1,LM3
      IF (TNMP(IA,IB,LVL).LT.TMIN) TMIN= TNMP(IA,IB,LVL)
      IF (TNMP(IA,IB,LVL).GT.TMAX) TMAX= TNMP(IA,IB,LVL)
      TML(IA,IB)= TNMP(IA,IB,LVL)
      TSDL(IA,IB)= STDN(IA,IB,LVL)
  360 CONTINUE
```

```
      ITLO= IFIX(TMIN)-15
      ITHI= IFIX(TMAX)+15

      DO 1000 MTH=1,4
      CALL DISTR(TML,TSDL,LM3)

C DISTR GIVES THE PROB. TO EXCEED THE DIFFERENT TEMP. VALUES
C OF THE ABOVE DEFINED TEMP. RANGE

C FIND THE TEMP. FOR WHICH THE PROB. NOT TO EXCEED IS .50,.75,.85

      DATA (PRV(IA),IA=1,3)/.50,.25,.15/
      DO 500 IA=1,3
      PNE(IA)= 1.-PRV(IA)
      JX=1
  420 IF (PROB(JX,MTH).GT.PRV(IA)) 430,480
  430 JX=JX+1
      GO TO 420
  480 TPR(IA,MTH)= DEGR(JX)-(PRV(IA)-PROB(JX,MTH))/(PROB(JX-1,MTH)-
     1PROB(JX,MTH))
  500 CONTINUE
      CALL FITNC

C FITNC FINDS A NORMAL DISTR. CURVE WHICH FOLLOWS THE UNIQUE DISTR.
C CURVE AS CLOSELY AS POSSIBLE

      IF (OPT(3).EQ.0) GO TO 1000
      CALL PINT(TINT,LVL)

C PINT GIVES PROB. ON TEMP.INTERVALS ABOUT THE USSA-TEMPERATURE

 1000 CONTINUE

C CALCULATE THE ANNUAL CASE BASED ON DATA FOR THE FOUR SEASONS.
C ANNUAL DATA ARE STORED IN COLUMN FIVE (MTH=5) OF EXISTING
C ARRAYS FOR SEASONAL DATA

      MTH= 5
      DO 1100 JA=1,ITR
      PSA= 0.
      DO 1080 IS=1,4
```

```
 1080 PSA= PSA+PROB(JA,IS)
 1100 PROB(JA,5)= .25*PSA
      DO 1140 IB=1,3
      JX=1
 1120 IF (PROB(JX,5).GT.PRV(IB)) 1125,1140
 1125 JX= JX+1
      GO TO 1120
 1140 TPR(IB,5)= DEGR(JX)-(PRV(IB)-PROB(JX,5))/
     1(PROB(JX-1,5)-PROB(JX,5))

      CALL FITNC

      IF (OPT(3).EQ.0) GO TO 1190
      CALL PINT(TINT,LVL)
 1190 IF (OPT(2).NE.1) GO TO 1300

C CONVERT TEMP.-ARRAYS FROM CELCIUS TO FAHRENHEIT

      DO 1200 J=1,ITK
 1200 DEGR(J)= CCF(DEGR(J))
      DO 1220 IB=1,5
      DO 1220 IA=1,3
 1220 TPR(IA,IB)= CCF(TPR(IA,IB))
      DO 1230 K= 1,NINT
 1230 TIM(K)= 1.8*TIM(K)
      DO 1235 M=1,5
      TMN(M)= CCF(TMN(M))
 1235 SCALC(M)= 1.8*SCALC(M)
 1300 CONTINUE

C PRINT CALC. SEASONAL AND ANNUAL DATA FOR THE PARTICULAR ALTITUDE

      PRINT 1410,(SEASON(NS),NS=1,4)
      IF (REV.EQ.0.) 1412,1414
 1412 PRINT 1415, (DIST(I),(TMMP(I,MTH,LVL),STDN(I,MTH,LVL),
     1MTH=1,4),I=1,LM3)
      GO TO 1418
 1414 PRINT 1415, (DIST(I),(TMMP(LM3+1-I,MTH,LVL),STDN(LM3+1-I,
     1MTH,LVL),MTH=1,4),I=1,LM3)
 1418 IT= OPT(2)
      PRINT 1420, UNIT(IT)
```

```
      IF (OPT(1).EQ.0) GO TO 1450
      PRINT 1430, (SEASON(NS),NS=1,4)
      PRINT 1435, (DEGR(J),(PROB(J,MTH),MTH=1,5),J=1,ITR)
 1450 PRINT 1460,(SEASON(NS),NS=1,4)
      PRINT 1465, (PNE(K),(TPR(K,MTH),MTH=1,5),K=1,3)
      IF (OPT(1).EQ.0.OR.OPT(3).EQ.0) GO TO 1500
      PRINT 1480, (SEASON(NS),NS=1,4)
      PRINT 1485,(TIM(L),(PINV(L,MTH),MTH=1,5),L=1,NINT)
 1500 PRINT 1510,(SEASON(NS),NS=1,4)
      PRINT 1515, (TMN(MTH),MTH=1,5),(SCALC(MTH),MTH=1,5)
      PRINT 1530, (EAVR(MTH),MTH=1,5),(EMAX(MTH),MTH=1,5)

C WRITE GRAPHICAL OUTPUT DATA ON BINARY TEJP FOR PROCESSING BY
C THE SC-4020 MACHINE

      IF (NCASE.AND.LVL.EQ.1) 1610,1615
 1610 IRR= 0
 1615 IF (IRR.EQ.0) 1630,1620
 1620 PRINT 1625, IRR
      GO TO 2000
C ADJUST TEMP.RANGE TO ATTAIN OPTIMUM READABILITY ON PLOTS
 1630 I1= 0
      I2= 0
      DO 1650 J=1,ITR
      IF (I2.EQ.5) GO TO 1650
      I2= 0
      DO 1640 MTH=1,5
      IF (PROB(J,MTH).LT..995.AND.I1.EQ.0) 1635,1638
 1635 JCL= J
      I1= 1
 1638 IF (PROB(J,MTH).LT..005) I2= I2+1
 1640 CONTINUE
      JCH= J
 1650 CONTINUE
      ITC= JCH-JCL+1
      DO 1655 J= JCL,JCH
      JC= J-JCL+1
 1655 DEGA(JC)= DEGR(J)
      DO 1720 MTH= 1,5
      NTAPE= 1
      DO 1660 J= JCL,JCH
```

```
      JC= J-JCL+1
 1660 PROD(JC)= PROB(J,MTH)
      CALL WBIN(DEGA,PROD,ITC,NTAPE,IRR)

C WBIN FEEDS ARGUMENTS TO THE 6600-SYSTEM TAPE WRITING SUB-
C ROUTINE WRTETP

      IF (OPT(3).EQ.0) GO TO 2000
      NTAPE= 2
      DO 1680 K=1,NINT
 1680 PIOD(K)= PINV(K,MTH)
 1720 CALL WBIN (TIM,PIOD,NINT,NTAPE,IRR)
 2000 CONTINUE
 3000 CONTINUE

      DATA (SEASON(NS),NS=1,4)/7HJANUARY,5HAPRIL,4HJULY,7HOCTOBER/
      DATA (UNIT(IT),IT=1,2)/10HFAHRENHEIT,10H  CELCIUS /
  130 FORMAT (3I6,F12.2)
  150 FORMAT (/////20X,*SEASONAL AND ANNUAL TEMP. DATA FOR GREAT
     1CIRCLE AIR ROUTES*)
  160 FORMAT (//20X,*OPT(1)=*,I3,5X,*OPT(2)=*,I3,5X,*OPT(3)=*,I3)
  260 FORMAT (80H
     1                                  )
  270 FORMAT (*1*,20X,*CASE NO.*,I5,* OUT OF NROUTE=*,I5//)
  275 FORMAT (10X,45H*********************************************)
  290 FORMAT (4F12.2)
 1380 FORMAT (/10X,*START POINT LATITUDE  =*,F8.2/22X,*LONGITUDE =*,
     1F8.2/10X,*END  POINT  LATITUDE  =*,F8.2/22X,*LONGITUDE =*,F8.2)
 1400 FORMAT (//10X,*ALTITUDE=*,I7,*FT*/10X,20H*******************)
 1410 FORMAT (///10X,*MEAN/ST.DEV. FOR POINTS ALONG THE ROUTE*,
     15X,15H*** CELCIUS ***/10X,*DIST N.M.*,5X,4(A9,7X)/)
 1415 FORMAT (12X,F4.0,2X,4(7X,F5.1,*/*,F3.1))
 1420 FORMAT (///10X,*TEMPERATURE UNIT IN FOLLOWING  TABLES IS*,
     15X,4H*** ,A10,4H ***)
 1430 FORMAT (///10X,*PROBABILITY TO EXCEED GIVEN TEMP.VALUES*/10X,
     1*TEMP*,11X,4(A9,3X),*ANNUAL*/)
 1435 FORMAT (10X,F6.1,3X,5(5X,F7.5))
 1460 FORMAT (///10X,*TEMP. THAT CORRESPOND TO GIVEN PROB. N O T TO*,
     1* BE EXCEEDED*/10X,*PROB.VALUE*,5X,4(A9,3X),*ANNUAL*/)
 1465 FORMAT (14X,F4.2,5(7X,F5.1))
 1480 FORMAT (///10X,*PROBABILITY ON INTERVALS ABOUT THE USSA-TEMP*/
```

```
     1/10X,*INT.MEDIAN*,6X,4(A9,3X),*ANNUAL*/)
1485 FORMAT (12X,*STD*,F5.1,5(5X,F7.5))
1510 FORMAT (///10X,*FIT A NORMAL CURVE TO THE*,
     1* ROUTE DISTR.*/25X,4(A9,3X),*ANNUAL*/)
1515 FORMAT (10X,*MEAN TEMP=*,5(5X,F7.2)/10X,
     1*ST. DEV. =*,5(5X,F7.2))
1530 FORMAT (/10X,*RESEMBLANCE OF FITTED CURVE TO ROUTE DISTR.*/
     110X,*DEVIATION IN PROBABILITY VALUES FOR CALC. TEMPERATURES*//
     210X,*ARIT.MEDIAN DEV.=*,5(F5.3,7X)/10X,*MAXIMUM   DEV.  =*,
     35(F5.3,7X))
1625 FORMAT (///*AN ERROR SENSED IN WRITING ON BINARY TEJP*/
     1*SEE DOC. D6-19175TN FOR ANALYSIS - ERROR KEY) IRR=*,I4/
     2*ALL FURTHER WRITING ON PLOT-PROCESS TEJPS BYPASSED*)

      ENDFILE 1
      ENDFILE 2
      END
```

```
      SUBROUTINE TEMP(GLAT,GLNG,NALT)

C TEMP CALCULATES MEAN- AND ST.DEV. DATA FOR POINTS ABOUT 200N.M.
C APART ALONG THE GIVEN ROUTE

      COMMON A,TNMP,STDN,LM3,DIST,ITHI,ITLO,ITR,MTH,PROB,TPR,REV,
     1TMN,SCALC,USSA,PRI,PINV,TIM,NINT,DEGR,LALT,I55C,EMAX,EAVR
      DIMENSION A(1117,4,2),TNMP(57,4,2),STDN(57,4,2),DIST(57),
     1PROB(70,5),TPR(3,5),TMN(5),SCALC(5),USSA(5),PRI(30,5),
     2PINV(30,5),TIM(30),DEGR(70),LALT(5),EMAX(5),EAVR(5)
      DIMENSION CPHI(2),CLMB(2),TDPHI(2),TDLMB(2),TRPHI(2),
     1TRLMB(2),RPHI(57),RLMB(57),GLAT(2),GLNG(2)

C SPECIFY DATA DECODING AND CONVERT ROUTE COORDINATES

      TEMPF(X)=FLOAT(IFIX(X/100.))/10.
      STDVF(X)=ABS((X-TEMPF(X)*1000.)/10.)
      PTNF(W,X,Y,Z)=W*FLOAT(IFIX(PHI/5.))+X*FLOAT(IFIX(AMB/Y))+Z
      IRNDF(X)=X+SIGN(.5,X)
      RADEG=1.74533E-02
      DEGRA=57.29578
      RE = 3.4377468E3

3003  DO 2009 I=1,2
      CPHI(I)= (GLAT(I)-FLOAT(IFIX(GLAT(I))))*5./3.+FLOAT(IFIX(GLAT(I)))
2009  CLMB(I)= (GLNG(I)-FLOAT(IFIX(GLNG(I))))*5./3.+FLOAT(IFIX(GLNG(I)))
      DO 21 I=1,2
      TDPHI(I)=90.-CPHI(I)
      IF (CLMB(I)) 22,23,23
   22 TDLMB(I)=360.+CLMB(I)
      GO TO 24
   23 TDLMB(I)=CLMB(I)
   24 TRPHI(I)=TDPHI(I)*RADEG
   21 TRLMB(I)=TDLMB(I)*RADEG
      REV= 0.
      IF(ABS(TDLMB(1)-TDLMB(2))-180.)51,51,52
   51 SAVE=AMAX1(TRLMB(1),TRLMB(2))
      TRLMB(2)=AMIN1(TRLMB(1),TRLMB(2))
      TRLMB(1)=SAVE
      GO TO 53
   52 SAVE=AMIN1(TRLMB(1),TRLMB(2))
```

```
      TRLMB(2)=AMAX1(TRLMB(1),TRLMB(2))
      TRLMB(1)=SAVE
   53 TDLMBT=TRLMB(2)/RADEG
      IF(ABS(TDLMBT-TDLMB(2))-0.001) 54,54,55
   55 SAVE=TRPHI(2)
      TRPHI(2)=TRPHI(1)
      TRPHI(1)=SAVE
      REV= 1.
C          CALCULATE POINTS ON THE GREAT CIRCLE ROUTE                    54
   54 COSPH1=COS(TRPHI(1))
      COSPH2=COS(TRPHI(2))
      SINPH1=SIN(TRPHI(1))
      SINPH2=SIN(TRPHI(2))
      TRDLNG=TRLMB(2)-TRLMB(1)

   25 GCDA=ACOS(COSPH1*COSPH2+SINPH1*SINPH2*COS(TRDLNG))
   27 GCD=RE*ABS(GCDA)
      IGCD = GCD+0.5
   28 INT=AMAX1(GCD/200.0+1.1)
      GCSGRA=GCDA/FLOAT(INT+1)
      GCDA=ABS(GCDA)
      SIND=SIN(GCDA)
      ANGLE=2.*ASIN(SQRT((COS(GCDA-TRPHI(1))-COSPH2)/2./SINPH1/SIND))

   63 RPHI(1)=TRPHI(1)
      RPHI(INT+2)=TRPHI(2)
      RLMB(1)=TRLMB(1)
      RLMB(INT+2)=TRLMB(2)
      LM2=INT+1
      DO 47 IPT=2,LM2
      SINDI=SIN(GCSGRA*FLOAT(IPT-1))
      RPHI(IPT)=ACOS(COS(GCSGRA*FLOAT(IPT-1))*COSPH1+SINDI*SINPH1*COS
     1(ANGLE))
      RLMB(IPT)=TRLMB(1)-2.*ASIN(SQRT((COS(TRPHI(1)-RPHI(IPT))-COS
     1(GCSGRA*FLOAT(IPT-1)))/2./SINPH1/SIN(RPHI(IPT))))
      IF(RLMB(IPT)) 41,47,47
   41 RLMB(IPT)=6.283185+RLMB(IPT)
   47 CONTINUE
```

```
C     I N T E R P O L A T I O N     A T     R O U T E     P O I N T S

      LM3=LM2+1
      DO 2100 IPT=1,LM3
  700 PHI=FLOAT(IFIX(RPHI(IPT)*100.*DEGRA))/100.
      AMB=FLOAT(IFIX(RLMB(IPT)*50.*DEGRA))/50.
      PHIMOD=AMOD(PHI,5.)
      CF1=PHIMOD
      IF (PHIMOD) 701,702,701
  701 IF(AMOD(AMB,20.)) 706,1700,706
  702 IF(AMOD(AMB,20.)) 703,1800,703
  703 IF(AMOD(AMB,10.)) 1600,704,1600
  704 IF (PHI-150.) 705,1800,1600
  705 IF (PHI-30.) 1600,1800,1800
  706 IF(AMOD(AMB,10.)) 707,708,707
  707 IF (PHI-5.) 1200,2000,709
  708 IF (PHI-150.) 711,2000,713
  709 IF (PHI-175.) 1100,2000,1500
  711 IF (PHI-30.) 712,2000,1700
  712 IF(PHI-25.) 714,2000,1300
  713 IF(PHI-155.) 1400,2000,715
  714 IF (PHI-5.) 1400,2000,1100
  715 IF (PHI-175.) 1100,2000,1300

C     THE GENERAL 4-POINT CASE                                    1100

 1100 IF (PHI-25.) 1101,2000,1102
 1101 C=20.
      D=3.
      H=-17.
      GO TO 1103
 1102 IF (PHI-30.) 1104,2000,1105
 1104 C=10.
      D=98.
      G=20.
      H=78.
      GO TO 1106
 1105 IF (PHI-150.) 1107,2000,1108
 1107 C=10.
      D=-87.
      H=-125.
```

```
      A=37.
      GO TO 1109
1108  IF (PHI-155.) 1110,2000,1111
1110  C=20.
      D=1023.
      G=10.
      H=985.
      GO TO 1106
1111  C=20.
      D=453.
      H=433.
1103  A=19.
1109  G=C
      GO TO 1112
1106  A=0.
1112  N1=PTNF(A,1.,C,D)
      N3=PTNF(A,1.,G,H)
      CF2=AMOD(AMB,C)
      CF3=AMOD(AMB,G)
      DO 1113 LVL=1,NALT
      DO 1113 MTH=1,4
      TNMP(IPT,MTH,LVL)=(PHIMOD*(TEMPF(A(N1,MTH,LVL))*CF2+TEMPF(A(N1-1,M
     XTH,LVL))*(C-CF2))/C+(5.-PHIMOD)*(TEMPF(A(N3,MTH,LVL))*(G-CF3)+TEMP
     XF(A(N3+1,MTH,LVL))*CF3)/G)/5.
1113  STDN(IPT,MTH,LVL)=(PHIMOD*(STDVF(A(N1,MTH,LVL))*CF2+STDVF(A(N1-1,M
     XTH,LVL))*(C-CF2))/C+(5.-PHIMOD)*(STDVF(A(N3,MTH,LVL))*(G-CF3)+STDV
     XF(A(N3+1,MTH,LVL))*CF3)/G)/5.
      GO TO 2100

C     THE GENERAL 3-POINT CASE WITHIN 5 DEGREES OF THE NORTH POLE          1200

1200  N1=PTNF(0.,1.,20.,3.)
      N3=PTNF(0.,0.,1.,1.)
      CF1=AMOD(AMB,20.)
      DO 1201 LVL=1,NALT
      DO 1201 MTH=1,4
      TNMP(IPT,MTH,LVL)=(PHI*(CF1*TEMPF(A(N1,MTH,LVL))+(20.-CF1)*TEMPF(A
     X(N1-1,MTH,LVL)))/20.+(5.-PHI)*TEMPF(A(N3,MTH,LVL)))/5.
1201  STDN(IPT,MTH,LVL)=(PHI*(CF1*STDVF(A(N1,MTH,LVL))+(20.-CF1)*STDVF(A
     X(N1-1,MTH,LVL)))/20.+(5.-PHI)*STDVF(A(N3,MTH,LVL)))/5.
      GO TO 2100
```

```
C     THE SPECIAL 3-POINT CASE WITHIN 5 DEGREES OF THE SOUTH POLE OR     1300
C     THE SPECIAL 3-POINT CASE BETWEEN 25 AND 30 DEGREES LATITUDE

 1300 IF (PHI-30.) 1301,2000,1302
 1301 D=79.
      F=1.
      H=97.
      GO TO 1303
 1302 D=1099.
      F=0.
      H=1117.
 1303 N1=PTNF(0.,1.,20.,D)
      N3=PTNF(0.,F,10.,H)
      DO 1304 LVL=1,NALT
      DO 1304 MTH=1,4
      TNMP(IPT,MTH,LVL)=(5.-PHIMOD)*(TEMPF(A(N1,MTH,LVL))+TEMPF(A(N1-1,M
     XTH,LVL))1)/10.+PHIMOD*TEMPF(A(N3,MTH,LVL))/5.
 1304 STDN(IPT,MTH,LVL)=(5.-PHIMOD)*(STDVF(A(N1,MTH,LVL))+STDVF(A(N1-1,M
     XTH,LVL)))/10.+PHIMOD*STDVF(A(N3,MTH,LVL))/5.
      GO TO 2100

C     THE SPECIAL 3-POINT CASE WITHIN 5 DEGREES OF THE NORTH POLE OR     1400
C     THE SPECIAL 3-POINT CASE BETWEEN 150 AND 155 DEGREES LATITUDE

 1400 IF (PHI-5.) 1401,2000,1402
 1401 D=3.
      F=0.
      H=1.
      GO TO 1403
 1402 D=1023.
      F=1.
      H=985.
 1403 N1=PTNF(0.,1.,20.,D)
      N3=PTNF(0.,F,10.,H)
      DO 1404 LVL=1,NALT
      DO 1404 MTH=1,4
      TNMP(IPT,MTH,LVL)=PHIMOD*(TEMPF(A(N1,MTH,LVL))+TEMPF(A(N1-1,MTH,LV
     XL))1)/10.+(5.-PHIMOD)*TEMPF(A(N3,MTH,LVL))/5.
 1404 STDN(IPT,MTH,LVL)=PHIMOD*(STDVF(A(N1,MTH,LVL))+STDVF(A(N1-1,MTH,LV
     XL)))/10.+(5.-PHIMOD)*STDVF(A(N3,MTH,LVL))/5.
```

```
      GO TO 2100

C     THE GENERAL 3-POINT CASE WITHIN 5 DEGREES OF THE SOUTH POLE      1500

 1500 N1=PTNF(0.,1.,20.,1099.)
      N3=PTNF(0.,0.,1.,1117.)
      CF1=AMOD(AMB,20.)
      DO 1501 LVL=1,NALT
      DO 1501 MTH=1,4
      TNMP(IPT,MTH,LVL)=(180.-PHI)*(CF1*TEMPF(A(N1,MTH,LVL))+(20.-CF1)*T
     XEMPF(A(N1-1,MTH,LVL)))/100.+(PHI-175.)*TEMPF(A(N3,MTH,LVL))/5.
 1501 STDN(IPT,MTH,LVL)=(180.-PHI)*(CF1*STDVF(A(N1,MTH,LVL))+(20.-CF1)*S
     XTDVF(A(N1-1,MTH,LVL)))/100.+(PHI-175.)*STDVF(A(N3,MTH,LVL))/5.
      GO TO 2100

C     THE SPECIAL 2-POINT CASE ON A LATITUDE AN EVEN MULTIPLE OF 5     1600

 1600 IF (PHI-30.) 1601,1602,1602
 1601 D=-16.
      GO TO 1603
 1602 IF (PHI-150.) 1604,1604,1605
 1605 D=434.
 1603 A=19.
      C=20.
      GO TO 1606
 1604 A=37.
      C=10.
      D=-124.
 1606 N1=PTNF(A,1.,C,D)
      CF1=AMOD(AMB,C)
      DO 1607 LVL=1,NALT
      DO 1607 MTH=1,4
      TNMP(IPT,MTH,LVL)=(TEMPF(A(N1,MTH,LVL))*CF1+TEMPF(A(N1-1,MTH,LVL))
     X*(C-CF1))/C
 1607 STDN(IPT,MTH,LVL)=(STDVF(A(N1,MTH,LVL))*CF1+STDVF(A(N1-1,MTH,LVL))+
     X*(C-CF1))/C
      GO TO 2100

C     THE SPECIAL 2-POINT CASE ON A LONGITUDE AN EVEN MULTIPLE OF 20   1700
C     OR AN EVEN MULTIPLE OF 10 BETWEEN 30 AND 150 DEGREES LATITUDE
```

```
1700 IF (PHI-5.) 1701,2000,1702
1701 A=0.
     B=1.
     C=20.
     D=2.
     F=0.
     G=1.
     H=1.
     GO TO 1703
1702 IF (PHI-25.) 1704,2000,1705
1704 D=2.
     G=20.
     H=-17.
     GO TO 1706
1705 IF (PHI-30.) 1707,2000,1708
1707 A=0.
     C=10.
     D=97.
     G=20.
     H=78.
     GO TO 1709
1708 IF (PHI-150.) 1710,2000,1711
1710 A=37.
     C=10.
     D=-88.
     G=10.
     H=-125.
     GO TO 1709
1711 IF (PHI-155.) 1712,2000,1713
1712 A=0.
     D=1022.
     G=10.
     H=985.
     GO TO 1714
1713 IF (PHI-175.) 1715,2000,1716
1715 D=452.
     G=20.
     H=433.
1706 A=10.
1714 C=20.
1709 B=1.
```

```
      F=1.
      GO TO 1703
 1716 A=0.
      B=0.
      C=1.
      D=1117.
      F=1.
      G=20.
      H=1098.
 1703 E=A
      N1=PTNF(A,B,C,D)
      N3=PTNF(E,F,G,H)
      DO 1717 LVL=1,NALT
      DO 1717 MTH=1,4
      TMMP(IPT,MTH,LVL)=(TEMPF(A(N1,MTH,LVL))*PHIMOD+TEMPF(A(N3   ,MTH,LV
     XL))*(5.-PHIMOD))/5.
 1717 STDN(IPT,MTH,LVL)=(STDVF(A(N1,MTH,LVL))*PHIMOD+STDVF(A(N3   ,MTH,LV
     XL))*(5.-PHIMOD))/5.
      GO TO 2100

C     THE SPECIAL 1-POINT CASE ON A DATA POINT                          1800

 1800 IF (PHI) 2000,1801,1802
 1801 D=1.
      GO TO 1803
 1802 IF (PHI-30.) 1804,1805,1805
 1804 D=-17.
      GO TO 1806
 1805 IF (PHI-180.) 1808,1807,2000
 1807 D=1117.
 1803 A=0.
      B=0.
      GO TO 1809
 1808 IF (PHI-150.) 1811,1811,1810
 1810 D=433.
 1806 B=1.
      A=19.
 1809 C=20.
      GO TO 1812
 1811 D=-125.
      A=37.
```

```
      B=1.
      C=10.
 1812 N1=PTNF(A,B,C,D)
      DO 1813 LVL=1,NALT
      DO 1813 MTH=1,4
      TNMP(IPT,MTH,LVL)=TEMPF(A(N1,MTH,LVL))
 1813 STDN(IPT,MTH,LVL)=STDVF(A(N1,MTH,LVL))

 2100 CONTINUE

C ACCUMULATED FLIGHT DISTANCE

      F1=FLOAT(IGCD)/FLOAT(LM2)
      F2=0.0
      DO 450 IPT=1,LM3
      DIST(IPT)= FLOAT(IRNDF(F2))
      F2=F2+F1
  450 CONTINUE

C CHECK FOR GEOGRAPHIC REGION WHERE NO RAW DATA AVAILABLE

      SLD= 3.1415927*29./36.
      DO 2500 LVL=1,NALT
      IF (LALT(LVL).EQ.68000) 2400,2500
 2400 DO 2500 IPT=1,LM3
      IF (RPHI(IPT).GT.SLD) 2420,2500
 2420 I55S= 1
      PRINT 2460
 2460 FORMAT(*METROLOGICAL DATA NOT AVAILABLE ON 68000FT*,
     1* SOUTH OF 55S. LATITUDE*//*SPECIFIED ROUTE ENTERS*,
     2* THIS REGION*)
 2500 CONTINUE
      GO TO 3000
 2000 WRITE OUTPUT TAPE 6,2001
 2001 FORMAT(1H05X39HAN ERROR OCCURRED IN INTEGER ARITHMETIC)
 3000 RETURN
      END
```

```
      SUBROUTINE DISTR(XMEAN,XSTD,NP)

C DISTR CALCULATES THE PROB. TO EXCEED THE DIFFERENT TEMP.VALUES
C OF THE ADOPTED TEMP. RANGE

      COMMON A,TNMP,STDN,LM3,DIST,ITHI,ITLO,ITR,MTH,PROB,TPR,REV,
     1TMN,SCALC,USSA,PRI,PINV,TIM,NINT,DEGR,LALT,ISSS,EMAX,EAVR
      DIMENSION A(1117,4,2),TNMP(57,4,2),STDN(57,4,2),DIST(57),
     1PROB(70,5),TPR(3,5),TMN(5),SCALC(5),USSA(5),PRI(30,5),
     2PINV(30,5),TIM(30),DEGR(70),LALT(5),EMAX(5),EAVR(5)
      DIMENSION XMEAN(57,4),XSTD(57,4)
      ITR= ITHI-ITLO+1
      DO 80 J=1,ITR
      PSUM= 0.
      DEGR(J)= ITLO+J-1
      DO 70 I=1,NP
      PIND= 1.-CNORML(DEGR(J),-100.*XSTD(I,MTH)+XMEAN(I,MTH),
     1XMEAN(I,MTH),XSTD(I,MTH))
   70 PSUM= PSUM+PIND
   80 PROB(J,MTH)= PSUM/NP
      RETURN
      END
```

```
      SUBROUTINE FITNC
C FITNC FINDS THE GAUSS-CURVE THAT CLOSEST FOLLOWS THE UNIQUE DISTR.
      COMMON A,TNMP,STDN,LM3,DIST,ITHI,ITLO,ITR,MTH,PROB,TPR,REV,
     1TMN,SCALC,USSA,PRI,PINV,TIM,NINI,DEGR,LALT,I55S,EMAX,EAVR
      DIMENSION A(1117,4,2),TNMP(57,4,2),STDN(57,4,2),DIST(57),
     1PROB(70,5),TPR(3,5),TMN(5),SCALC(5),USSA(5),PRI(30,5),
     2PINV(30,5),TIM(30),DEGR(70),LALT(5),EMAX(5),EAVR(5)
      DIMENSION SPRV(13),SIGMA(13),ST(13)
      DATA (SPRV(L),L=1,13)/.99865,.99379,.97725,.93319,.84134,
     1.69146,.50000,.30854,.15866,.06681,.02275,.00621,.00135/
      LLOW= 1
      LHIGH= 13
      L= 1
  825 IF (PROB(1,MTH).LT.SPRV(L)) 830,835
  830 LLOW= LLOW+1
      L= L+1
      GO TO 825
  835 L= 13
  840 IF (PROB(ITR,MTH).GT.SPRV(L)) 850,880
  850 LHIGH= LHIGH-1
      L= L-1
      GO TO 840
  880 DO 940 L=LLOW,LHIGH
      IF (L.EQ.7) GO TO 940
      J= 1
  900 IF (PROB(J,MTH).GT.SPRV(L)) 910,920
  910 J= J+1
      GO TO 900
  920 ST(L)= DEGR(J)-(SPRV(L)-PROB(J,MTH))/(PROB(J-1,MTH)-
     1PROB(J,MTH))
  940 CONTINUE
      TMN(MTH)= (ST(5)+ST(6)+TPR(1,MTH)+ST(8)+ST(9))*.2
      SSUM= 0.
      DO 1000 L=LLOW,LHIGH
      IF (L.EQ.7) GO TO 1000
      SIGMA(L)= 2.*ABS((ST(L)-TMN(MTH))/(L-7))
      SSUM= SSUM+SIGMA(L)
 1000 CONTINUE
      SCALC(MTH)= SSUM/(LHIGH-LLOW)
```

```
C ASSESS THE ACCURACY OF THE CURVE-FITTING, BY INDICATING AN
C ARITHMETIC MEAN- AND A EXTREME DEVIATION FROM THE ROUTE PROB.VALUE
      ES= 0.
      EMAX(MTH)= 0.
      DO 1200 J=1,ITR
      PFIT= 1.- CNORML(DEGR(J),-100.*SCALC(MTH)+TMN(MTH),TMN(MTH),
     1SCALC(MTH))
      EI= ABS(PROB(J,MTH) - PFIT)
      IF (EI.GT.EMAX(MTH)) EMAX(MTH)= EI
 1200 ES= ES + EI
      EAVR(MTH)= ES/ITR
      RETURN
      END
```

```
      SUBROUTINE PINT(TINT,LVL)

C PINT CALC. PROBABILITIES ON TEMP. INTERVALS ABOUT THE USSA-TEMP

      COMMON A,TNMP,STDN,LM3,DIST,ITHI,ITLO,ITR,MTH,PROB,TPR,REV,
     1TMN,SCALC,USSA,PRI,PINV,TIM,NINT,DEGR,LALT,I55,EMAX,EAVR
      DIMENSION A(1117,4,2),TNMP(57,4,2),STDN(57,4,2),DIST(57),
     1PROB(70,5),TPR(3,5),TMN(5),SCALC(5),USSA(5),PRI(30,5),
     2PINV(30,5),TIM(30),DEGR(70),LALT(5),EMAX(5),EAVR(5)
      DIMENSION TIL(30)
      IF (MTH.GT.1) GO TO 80
C DETERMINE NUMBER OF INTERVALS
      NNEG= IFIX((USSA(LVL)-ITLO)/TINT)+1
      NTOT= IFIX((ITHI-ITLO)/TINT)+1
   80 DO 300 K=1,NTOT
      IF(MTH.GT.1) GO TO 110
      TIL(K)= USSA(LVL)-TINT*(NNEG+1.5-K)
      TIM(K)= TINT*(K-1-NNEG)
  110 PRI(K,MTH)= 1.
      IF (DEGR(1).GE.TIL(K)) GO TO 300
      IF (DEGR(ITR).LE.TIL(K)) GO TO 260
      J=1
  170 DIFF= DEGR(J)-TIL(K)
      IF (DIFF) 200,210,210
  200 J=J+1
      GO TO 170
  210 PRI(K,MTH)= PROB(J,MTH)+(PROB(J-1,MTH)-PROB(J,MTH))*DIFF
      GO TO 300
  260 PRI(K,MTH)= 0.
  300 CONTINUE
      NINT= NTOT-1
      DO 360 KA=1,NINT
  360 PINV(KA,MTH)= PRI(KA,MTH)-PRI(KA+1,MTH)
      RETURN
      END
```

```
      SUBROUTINE WB1N(A1,A2,M,NTAPE,IRR)
C SUBROUTINE FEEDS DATA TO THE 6600-SYSTEM SUBROUTINE WRTETP
      DIMENSION A1(70),A2(70),B(16)
      NAME= 0
      CALL WRTETP(A1,1,NAME,M,1,B,0,0,NTAPE,IRR)
      IF (IRR.NE.0) GO TO 50
      NAME= 0
      CALL WRTETP(A2,1,NAME,M,1,B,0,0,NTAPE,IRR)
      IF (IRR.NE.0) GO TO 50
      GO TO 80
   50 ENDFILE NTAPE
   80 RETURN
      END
```

```
      FUNCTION CNORML(XH,XL,XM,XS)
C     S00887   CNORML   PS-497      CHIANG E. C. H.  661004 6600
      P(X)=.5*(1.-(1./(1.+.1411821*X+.0886027*X**2
     1+.0274349*X**3-.0039446*X**4+.0328975*X**5
     2)**8))
C              IF NM=1,X1 AND X2 SHOULD BE STANDARDIZED TO N(0,1)
      X1=(XH-XM)/XS
      X2=(XL-XM)/XS
 1000 Z1=X1=X1/1.414213567
      Z2=X2/1.414213567
      IF(Z1*Z2)1,2,3
C     WHEN Z1 AND Z2 HAVE DIFFERENT SIGN
    1 Z2=ABS(Z2)
      CNORML=P(Z2)+P(Z1)
      GO TO 100
C     TO FIND WHETHER Z1 OR Z2 IS 0
    2 CNORML=P(ABS(Z1+Z2))
      GO TO 100
C     WHEN Z1 AND Z2 HAVE THE SAME SIGN
    3 Z2=ABS(Z2)
      Z1=ABS(Z1)
      CNORML=ABS(P(Z2)-P(Z1))
  100 RETURN
      END
```

16-58402
Rev 6.0

```
850301          OLSSON,K.V.     6-8503  59-B
    5    99     1     0     0     9
    5    -5     7     7     9    -1    10    -1    11    -1
   12     1    13     1    21     1    15     3
   -1    25    47    48     0
    2     1     2     2
    2   310    80
SEASONAL AND ANNUAL DISTR.
FOR GIVEN ALT. AND ROUTE
   80   285   180    75
  550   860
-0-     JANUARY
  550   830
-1-     APRIL
  550   800
-7-     JULY
  550   770
-8-     OCTOBER
  550   740
---     ANNUAL
                              TEMPERATURE
                              PROBABILITY TO EXCEED
        0.          1.
    0   -1
    5    99     2     0     0     9
    5    -5     7     5     9    -1    10    -1    11    -1
   12     1    13     1    21     1    15     3
   -1    25    47    48     0
    2     1     2     2
    2   310    80
PROBABILITY ON INTERVALS
OF SPECIFIED WIDTH
   80   285   180    75
  550   860
-0-     JANUARY
  550   830
-1-     APRIL
  550   800
-7-     JULY
  550   770
```

-8- OCTOBER
550 740
--- ANNUAL

TEMP INTERVAL REF. TO STD.
PROBABILITY ON INTERVAL

0.0 0.4
0 0

## APPENDIX C

## INPUT DATA DESCRIPTION AND ARRANGEMENT

The table below describes the preparation of the data input cards.

| CARD | LOCATION COLUMN | INPUT ITEM | MODE OF NUMBER | DESCRIPTION |
|---|---|---|---|---|
| 1 | 1-6 | NALT | INT. | Number of altitudes to be used throughout the calculations. |
| | 7-12 | ALTI(1) | INT. | First altitude (feet) for which data is to be calculated. |
| | 13-18 | ALTI(2) | INT. | Second altitude in calculation. ALTI(2) must be larger than ALTI(1) (altitudes entered in order of increasing numbers). ALTI(2) omitted if NALT equal to one. |
| 2 | 1-6 | OPT(1) | INT. | Option; = 1 if printing of all calculated data, = 0 if not |
| | 7-12 | OPT(2) | INT. | Option; = 1 if temp. output in Fahrenheit, = 2 if Celcius |
| | 13-18 | OPT(3) | INT. | Option; = 1 if probability on intervals desired, = 0 if not |
| | 19-30 | TINT | REAL | Width of temp. intervals, can be omitted if OPT(3) = 0, OPT(2) controls input unit. |
| 3 | 1-6 | NROUTE | INT. | Number of routes to be calculated in the specified manner. |
| 4 | 1-80 | COMMENT | ALPHANUM | Description of route; This card must not be omitted. |
| 5 | 1-12 | GLAT(1) | REAL | Start point latitude in degrees and minutes to the conventional notation; north latitudes positive, south negative. |
| | 13-24 | GLNG(1) | REAL | Start points longitude in degrees and numbers to the conventional notation; west longitudes positive, east negative. |
| | 25-36 | GLAT(2) | REAL | End point latitude |
| | 37-48 | GLNG(2) | REAL | End point longitude |

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Input data to process first work is now complete. For additional routes, repeat cards 4 and 5 until specified NROUTE are imputed.

Input data to generate the sample case output shown in figures 5 through 7 are listed below:

COLUMNS

| 1 6 | 12 | 18 | 24 | 30 36 | 48 | 60 | 72 |
|---|---|---|---|---|---|---|---|
| 1 | 30,000 | | | | | | |
| 0 | 1 | 1 | 5 | | | | |
| | | | | | | | |
| 1 | | | | | | | |
| Johannesburg to London 4896 N.M. | | | | | | | |
| -26.08 | | -28.15 | | 51.28 | .27 | | |

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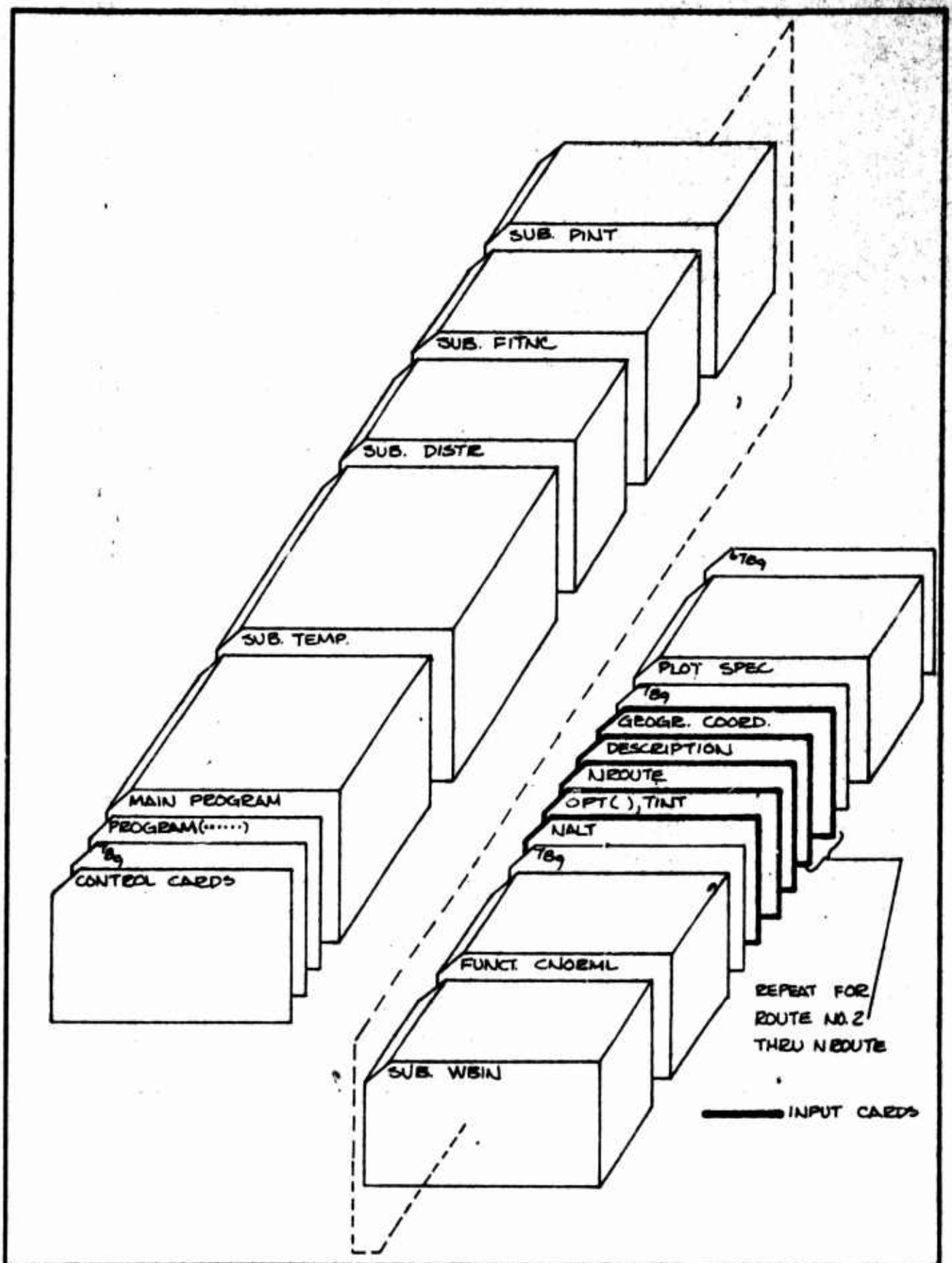


| | | | REVISED | DATE | | |
|---|---|---|---|---|---|---|
| CALC | | | | | DECK SET-UP | FIG. 19 |
| CHECK | | | | | | |
| APPD | | | | | | D6-58402 |
| APPD | | | | | THE BOEING COMPANY RENTON, WASHINGTON | PAGE 67 |
| Drn | DeB | | | | | |

YD 873 D-R3 6-7000

```
KV01,T36,CM110000.
ACCT 853301 P XM3DISTR.4D/OLSSON,K.V.     /59-B/655-5517/6-8503-00/B
REQUEST TAPE8.        (66-Z453/INPUT)
REWIND (TAPE8)
OFFLINE. S/C 4020 REQUEST
COMMENT. PROJECT FORM NO. 3                PROG X     AUTO
COMMENT. CAMERA 16MM            PROG X          FRAM 2
COMMENT. TYPE OF OUTPUT         VELLUM
COMMENT. OPER. INITIALS         FRAME COUNT          JOB NO.       TIME
REQUEST TAPE99,X.          (PLOT/SC4020)
COPYBF(EOF,TAPE99,3)
REWIND(TAPE99)
RUN(S)
LGO.
UNLOAD (TAPE8)
DROPFIL (TAPE8)
USERFL(ADVSYS,TEL093)
TEL093.
CHKTAPE(TAPE99)
EXIT.
COPYBF(EOF,TAPE99,3)
CHKTAPE(TAPE99)
UNLODE(TAPE99)
-
```

CONTROL CARDS

## APPENDIX E

### FORTRAN NOMENCLATURE

The following table gives the nomenclature for the main program and the subprograms. Only the more significant terms are included. The nomenclature for terms, whose values are stored in the COMMON region of the computer, are given first. In the table, dummy subscripts I, J and K are used to denote 1, 2 and 3rd dimension respectively.

NOMENCLATURE FOR THE COMMON STORAGE

| FORTRAN SYMBOL | DESCRIPTION | UNITS |
|---|---|---|
| A (I,J,K) | Meteorological data. Coded in the form ±aaabb, where ±aaa is mean-temp. in tenths and bb is standard deviation in tenths also.<br>I denotes location on the earth<br>J denotes month<br>K denotes altitude | C (Celius) |
| DEGR(I) | Temperatures calculated and used for one altitude | C |
| DIST(I) | Cumulative distance from start terminal to point i | N.M. |
| EAVR(I) | Average error in fitted normal curve | --- |
| EMAX(I) | Maximum error in fitted normal curve | --- |
| ITHI | Upper boundary of temp. range considered for one altitude. | C |
| ITLO | Lower boundary of temp. range considered for one altitude. | C |
| ITR | Number of temperature steps used in calculation | --- |
| I55S | Indicator for region of earth where meteorological raw data are not available (68000 ft, south of 55 S.lat.) | --- |
| LALT(I) | Altitude | FEET |

| FORTRAN SYMBOL | DESCRIPTION | UNITS |
|---|---|---|
| LM3 | Number of points i on the route | --- |
| MTH | Months number. 1 through 5 per following denotation.<br>1 for January<br>2 for April<br>3 for July<br>4 for October<br>5 for Annual | --- |
| NINT | Number of intervals employed for probability on intervals | --- |
| PINV(I,J) | Probability on individual temp. intervals of given width and median temperature. | N (Normalized) |
| PRI(I,J) | Cumulative probability value at lower boundary of interval | N |
| PROB(I,J) | Cumulative probability to exceed temp. values given by DEGR(I) | N |
| SCALC(I) | Standard deviation for fitted normal distribution curve | C |
| STDN(I,J,K) | Standard deviation for the points along the route. | C |
| TIM(I) | Interval median temperature | C |
| TMN(I) | Mean values for fitted normal distribution curves | C |
| TNMP(I,J,K) | Mean temp. for the points along the route | C |
| TPR(I,J) | Temperatures corresponding to .50, .75 and .85 probability not to exceed | C |
| USSA(I) | United States Standard Atmosphere, 1962 | C |

ADDITIONAL NOMENCLATURE FOR THE MAIN PROGRAM AND SUBPROGRAMS

For complete nomenclature to subroutine TEMP, see Document D6-6833TN.

| | | |
|---|---|---|
| ALTI (I) | Altitudes on which calculations are to be carried out. | Feet |

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| FORTRAN SYMBOL | DESCRIPTION | UNITS |
|---|---|---|
| CCF(Dummy) | Arithmetic statement functions for temperature conversion from Celcius to Fahrenheit. | F |
| GLAT(1) | Latitudes of terminal points | o.' |
| GLNG(I) | Longitudes of terminal points | o.' |
| IRR | Error indicator for writing on binary tapes | --- |
| LVL | Level (altitude) | FEET |
| NALT | Number of altitudes used in the calculations | --- |
| NROUTE | Number of routes | --- |
| NTAPE | Binary tape number | --- |
| OPT(I) | Options for calculations | --- |
| PIOD(I) | Array PINV(I,J) tranformed to 1-dimension | N |
| PROD(I) | Array PROB(I,J) transformed to 1-dimension | N |
| TML(I,J) | Array TEMP(I,J,K) transformed for 2-dim | C |
| TSDL(I,J) | Array STDN(I,J,K) transformed to 2-dim. | C |

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## LIST OF NOMENCLATURE

| Symbol | Description |
|---|---|
| $F_N(\vartheta)_i$ | Cumulative probability that T shall be less than or equal to $\vartheta$, for point "i" of a route. |
| $F_R(\vartheta)$ | Cumulative probability ( $T \leq \vartheta$ ) for the entire route. |
| $F_{RA}(\vartheta)$ | $F_R(\vartheta)$ for the annual case |
| $m_F$ | Mean value for fitted normal curve. |
| $m_i$ | Mean value for point "i" of a route. |
| $n$ | Number of points on a route, terminals included. |
| $\sigma_F$ | Standard deviation for fitter normal curve. |
| $\sigma_i$ | Standard deviation for point "i" of a route. |
| $t_{50}$ | Temperature for $F_R$ equal to 50 percent. |
| $t_\gamma$ | Interpolated temperature used when fitting a normal curve. |
| $T$ | Function that describes the occurrence of different temperatures $\vartheta$ at a given point. In this case a Gaussian function. |
| $\vartheta$ | Independent variable (temperature) |

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| 9 | 747 A/C Pack Ram Air Drag. Regional Temperature Distribution. | 28 |
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| 11 | 99, 90, 50, 10 and 1% Probability of Exceeding, Temperature. Continental United States combined with North Atlantic, Central and Southern Europe. | 33 |
| 12 | 99, 90, 50, 10 and 1% Probability of Exceeding, Temperature. Polar Region of Northern Hemisphere. | 34 |
| 13 | 99, 90, 50, 10 and 1% Probability of Exceeding, Temperature. Equatorial Region. | 35 |
| 14 | Seasonal and Annual Distribution for Specified Geographical Region. Continental United States at 30,000 ft. | 36 |
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| | 20 | | | | | | | | | 70 | | | | | | | |
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| | 23 | | | | | | | | | 73 | | | | | | | |
| | 24 | | | | | | | | | 74 | | | | | | | |
| | 25 | | | | | | | | | 75 | | | | | | | |
| | 26 | | | | | | | | | 76 | | | | | | | |
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AD 15468

REV SYM

# REVISIONS

| REV SYM | DESCRIPTION | DATE | APPROVAL |
|---|---|---|---|
| | | | |

AD 1546 C

AD690069

## II. SUMMARY

Accurate information concerning the statistical distribution of enroute ambient temperatures at airplane cruise altitudes is required for many trade studies and performance calculations, and is particularly important when system performance is highly temperature dependent as, for example, in airplane air-conditioning system studies. This document describes a method of calculating the statistical monthly (January, April, July and October) and annual temperature distribution on any Great Circle route for pressures of 700, 500, 300, 200, 150 100 and 50 millibars, corresponding approximately to altitudes of 10,000 feet, 18,000 feet, 30,000 feet, 40,000 feet, 45,000 feet, 53,000 feet and 68,000 feet.

The route temperature distributions are generated by a computer program. Inputs to the program are the coordinates of the terminal points. Output is in several forms, namely:

1. The route temperature distribution, showing the probability of exceeding any temperature, given in graphical form with the option of tabular form as well.
2. The percentage of the total time that the temperature lies within discrete intervals of specified medium and width, given in graphical form with the option of tabular form as well.
3. The mean and standard deviation of the normal curve which best approximates the actual temperature distribution, and the error associated with the normal curve approximation.

The graphical output is illustrated in Figures 6 and 7 for the Johannesburg to London route at 30,000 feet.

Meteorological data based on records compiled over long periods for a selected global network of points furnish the basis for the program.

Sections of an existing program (Boeing Document D6-6833TN, Program No. TAP003) are employed, as a subroutine, for the determination of mean temperatures and standard deviations at equidistant points 100-200

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## IV. CALCULATION OF TEMPERATURE DISTRIBUTION ON A GREAT CIRCLE ROUTE

### A. METEOROLOGICAL DATA

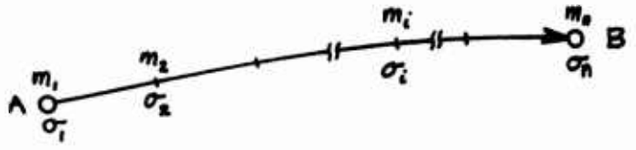
Meteorological data, based on records complied over long periods, have been obtained for a network of 1117 points covering the surface of the earth. The points are located at every latitude which is an exact multiple of five degrees. Within 60° latitude of the equator, the points are located at every longitude which is an exact multiple of ten degrees; on those latitudes which are farther than 60° from the equator the points are located at every longitude which is an exact multiple of twenty degrees. Each pole is represented by one point. The mean and standard deviation of a normal distribution fitted to the actual temperatures over a period of a month are recorded for each point. Data are available for January, April, July and October, these months being assumed to be representative of the seasons; and for pressures of 700, 500, 300, 200, 150, 100 and 50 millibar corresponding approximately to altitudes of 10,000 feet, 18,000 feet, 30,000 feet, 40,000 feet, 45,000 feet, 53,000 feet and 68,000 feet. Thus a total of 62,550 data values are available. A

### B. GREAT CIRCLE ROUTE CALCULATION

If the geographical coordinates of the terminals of a route are specified, the Great Circle route may be determined by standard methods (Reference 2 for example). The coordinates of most major airports can be found in Reference 1.

### C. CALCULATION OF ROUTE TEMPERATURE DISTRIBUTION

If a route is divided into a number of equidistant points, the mean temperature ($m_i$), and standard deviation ($\sigma_i$) at each point (for a given month and altitude) may be obtained by interpolation from adjacent data points (Reference 2). Then if the temperature at any

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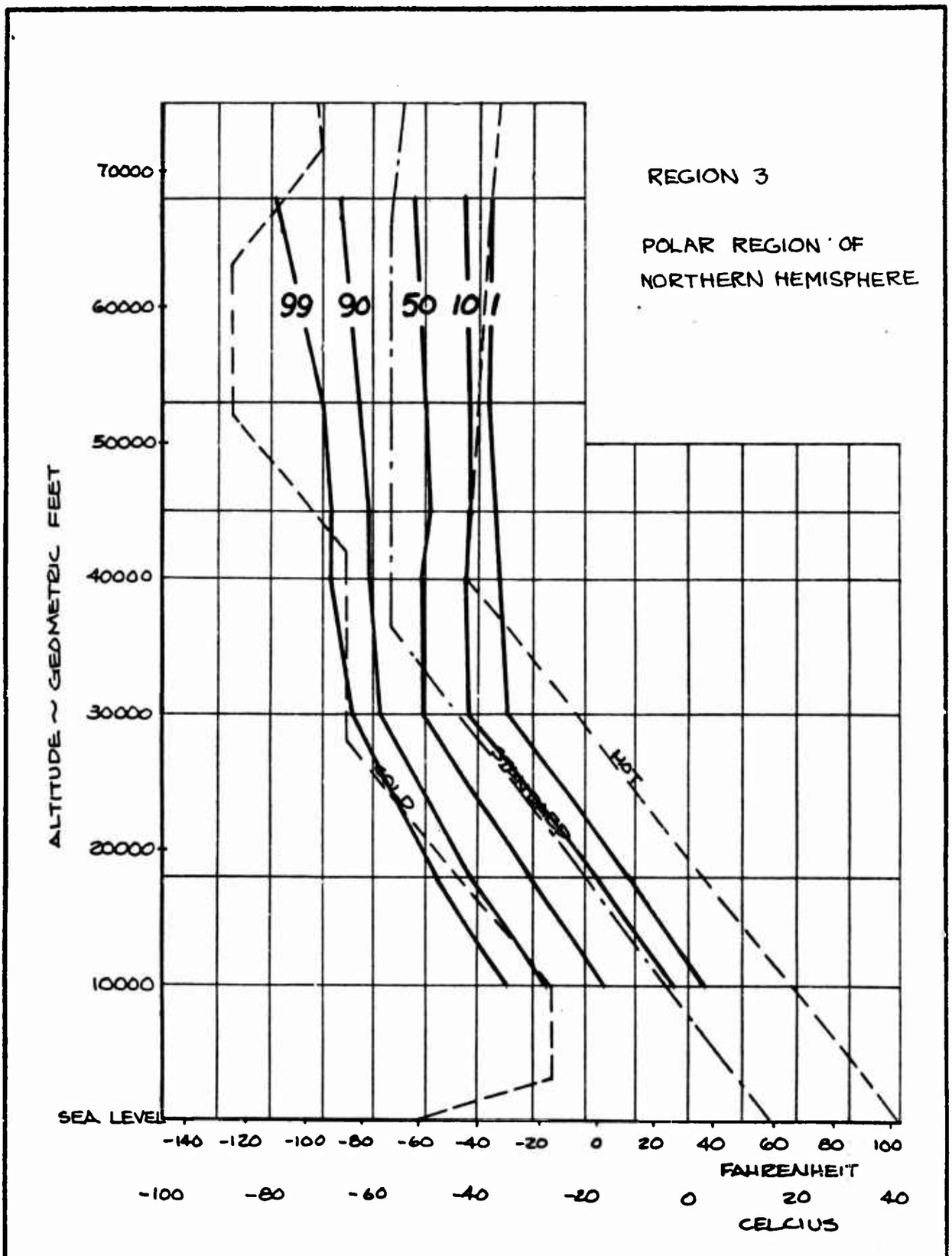
Input for the program is described in Appendix C, and sample data for the route Johannesburg to London are included for illustration. It should be noted that exactly antipodal points must not be specified as terminals of a route since such points do not give a uniquely defined Great Circle route. Furthermore, meteorological data are not available on the 700, 500 or the 50 millibar (10,000', 18,000' or 38,000' altitude) levels south of latitude 55 S. A diagnostic is printed if the Great Circle route enters this region on those altitudes. A

In order to reduce core storage requirements the DIMENSION statements have been written so that not more than two altitudes can be handled in any one run, and routes are restricted to a maximum length of 11,000 nautical miles.

Output data are in the form of graphs and tables and are self-explanatory. The plots are not labeled by route, but may be identified by the fact that they are generated in the same order that the routes are inputed. Tabular and graphical output corresponding to the input of Appendix C are shown in Figures 5 through 7.

Appendix D shows a complete deck assembly and lists the required control cards. The Fortran nomenclature is shown in Appendix E. The core storage requirement is $110000_8$ and the central processor time is approximately equal to

$$CPT = 21.5 + 3.8 \times NALT \times NROUTE \text{ seconds}$$




| | | | REVISED | DATE | 99, 90, 50, 10 AND 1 PER CENT PROBABILITY OF EXCEEDING TEMPERATURE | FIG. 12 |
|---|---|---|---|---|---|---|
| CALC | | | A | | | D6-58402 |
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| APPD | | | | | THE BOEING COMPANY RENTON, WASHINGTON | PAGE 34 |

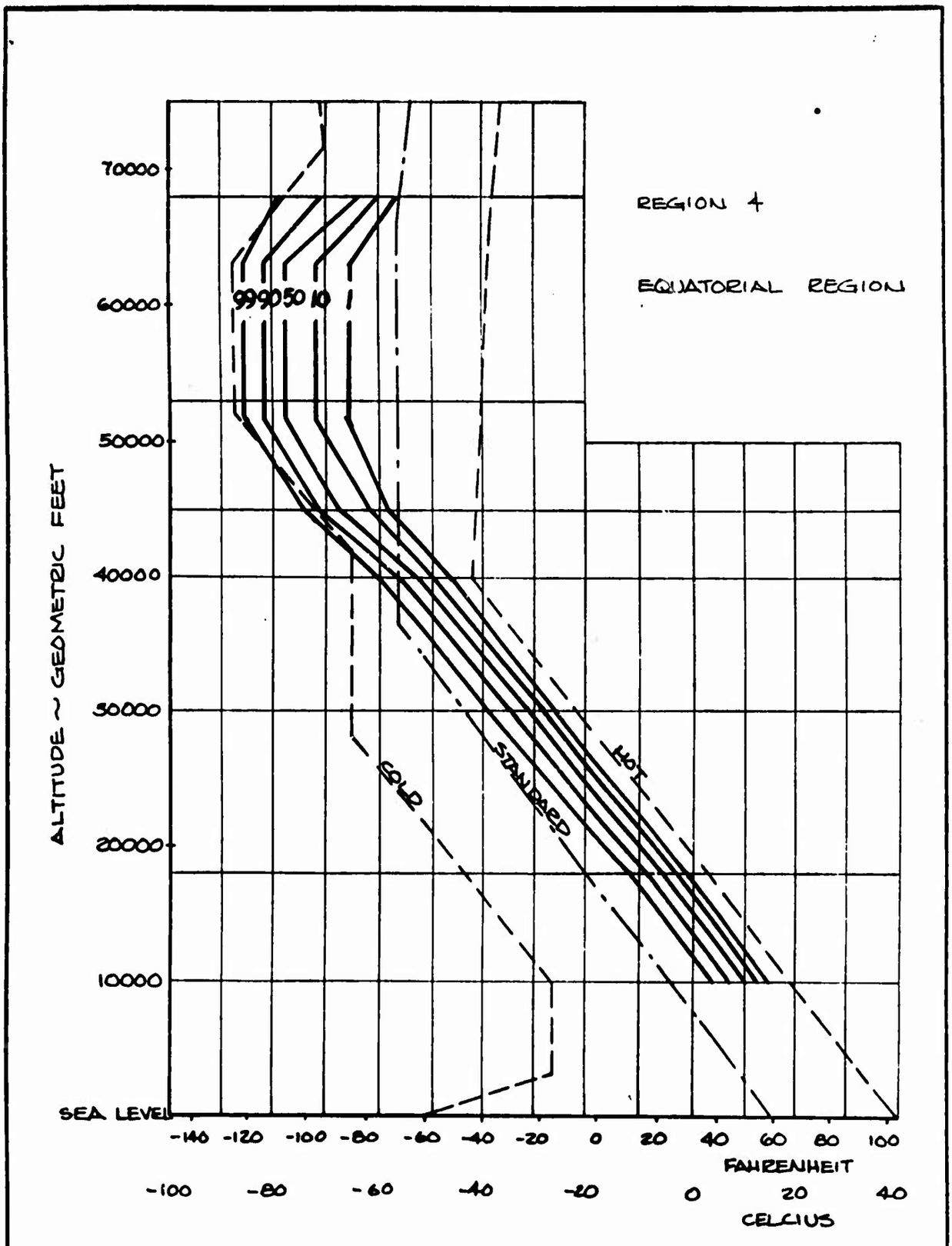


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FIG. 13
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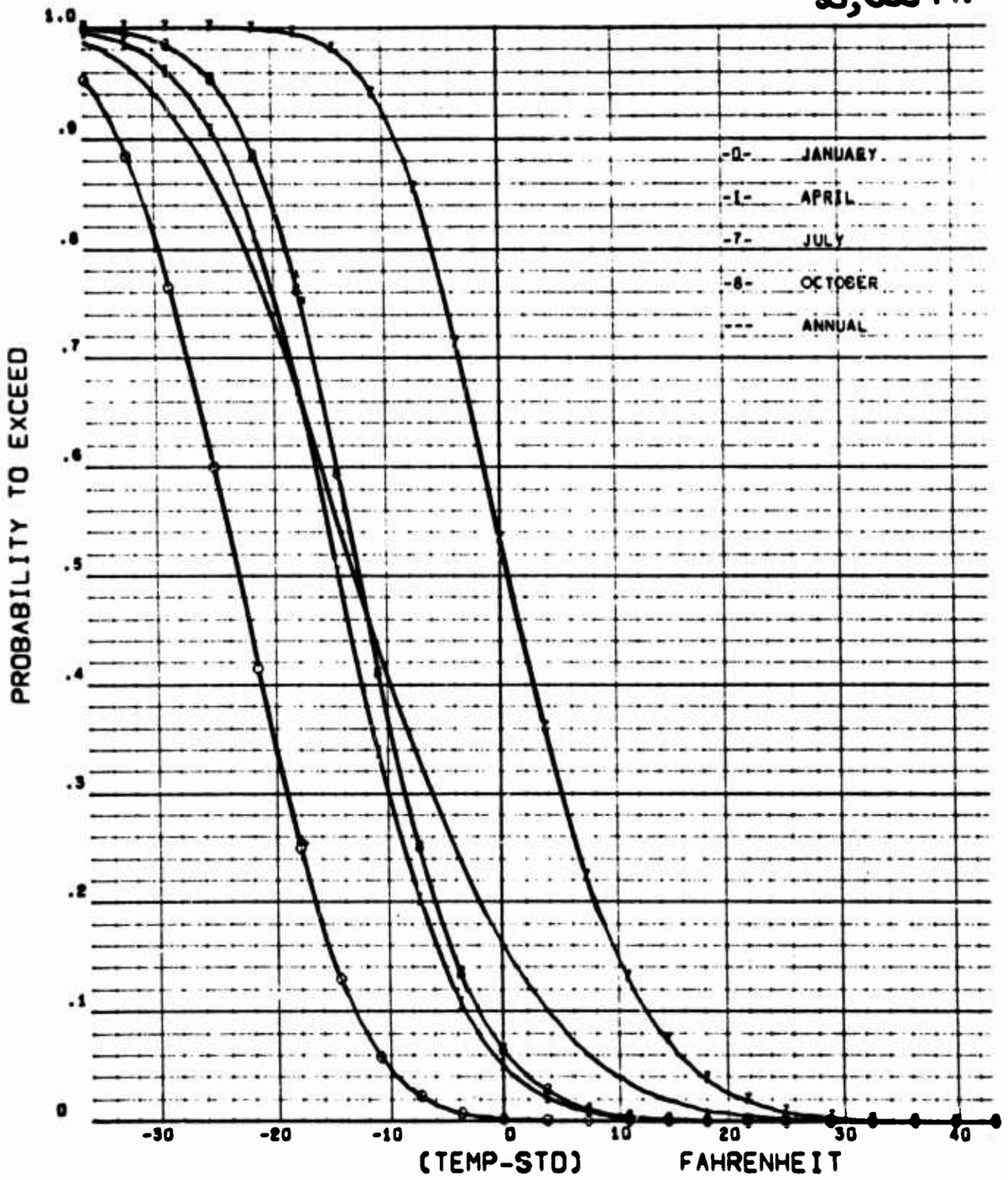
POLAR REGION
30,000 FT.

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| CALC | | | REVISED | DATE | SEASONAL AND ANNUAL DISTR. FOR SPEC. GEOGR. AREA |
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FIG. 16
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```
      B=1.
      C=10.
 1812 N1=PTNF(A,B,C,D)
      DO 1813 LVL=1,NALT
      DO 1813 MTH=1,4
      TNMP(IPT,MTH,LVL)=TEMPF(A(N1,MTH,LVL))
 1813 STDN(IPT,MTH,LVL)=STDVF(A(N1,MTH,LVL))

 2100 CONTINUE

C ACCUMULATED FLIGHT DISTANCE

      F1=FLOAT(IGCD)/FLOAT(LM2)
      F2=0.0
      DO 450 IPT=1,LM3
      DIST(IPT)= FLOAT(IRNDF(F2))
      F2=F2+F1
 450  CONTINUE

C CHECK FOR GEOGRAPHIC REGION WHERE NO RAW DATA AVAILABLE

      SLD= 3.1415927*29./36.
      DO 2500 LVL=1,NALT
      IF (LALT(LVL).LE.18000.OR.LALT(LVL).EQ.68000) 2400,2500
 2400 DO 2500 IPT=1,LM3
      IF (RPHI(IPT).GT.SLD) 2420,2500
 2420 I55S= 1
      PRINT 2460
 2460 FORMAT(*METROLOGICAL DATA NOT AVAILABLE*,
     1* SOUTH OF 55S. LATITUDE*//*SPECIFIED ROUTE ENTERS*,
     2* THIS REGION*)
 2500 CONTINUE
      GO TO 3000
 2000 WRITE OUTPUT TAPE 6,2001
 2001 FORMAT(1H05X39HAN ERROR OCCURRED IN INTEGER ARITHMETIC)
 3000 RETURN
      END
```

```
KVO1,T36,CM110000.
ACCT 850301 P XM3        4D/OLSSON,K.V.     /59-B/655-5517/6-8503-00/B
REQUEST TAPE8.          (66-X697/INPUT)
REWIND (TAPE8)
OFFLINE. S/C 4020 REQUEST
COMMENT. PROJECT FORM NO. 3                  PROG       AUTO X
COMMENT. CAMERA 16MM              PROG X          FRAM 2
COMMENT. TYPE OF OUTPUT           VELLUM
COMMENT. OPER. INITIALS           FRAME COUNT          JOB NO.       TIME
REQUEST TAPE99,X.          (PLOT/SC4020)
COPYBF(EOF,TAPE99,3)
REWIND(TAPE99)
RUN(S)
RFL(OFF)
MAP(OFF)
LGO.
UNLOAD (TAPE8)
DROPFIL (TAPE8)
USERFL(ADVSYS,TEL093)
MAP(OFF)
TEL093.
CHKTAPE(TAPE99)
EXIT.
COPYBF(EOF,TAPE99,3)
CHKTAPE(TAPE99)
UNLODE(TAPE99)
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CONTROL CARDS

# LIST OF ACTIVE PAGES

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AD 1548B

REV SYM

A

## REVISIONS

| REV SYM | DESCRIPTION | DATE | APPROVAL |
|---|---|---|---|
| A | Program capability expanded to include the 10,000 feet and 18,000 feet altitude levels. | 10/6/69 | K.V. Olsson |
| | | 10/6/69 | A.L.P. Lloyd |
| | | 10/6/69 | W.J. Melchior |

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